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WIRE TRIANGULAR TRUSS.

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[Read at the Stated Meeting, Wednesday, June 18, 1884.]

GENTLEMEN: I have the honor to call your attention to a new truss of which I had the idea, and which for permanent loads dispenses entirely with horizontal strains on the chords and allows to support a moving weight with lighter material than is generally done. It is made with steel wires isolated or united together in a form of cable or rope. I would recommend its application to different kinds of structures, such as elevated railroads, bridges, roofs, viaducts, acqueducts and others. To give you a general idea of the truss, I would say, take one-inch board and draw on it a rectangle 10 inches long and 5 inches high. (Fig. 1.) Call the four corners *A*, *B*, *C*, *D*, and at each of them drive a small wood screw. At the top screws *A* and *B* fasten the two ends of a wire, No. 20, of such a length that pressing it with the finger it deflects a little less than two inches. Pull on the centre of it with a spring balance, and when the deflection is two inches note the number of pounds indicated. Suppose it to be eight pounds. Fasten to the bottom screws *C* and *D* the two ends of another wire of same length as the first and with a third wire brace them together so that the deflection of each be two inches. You have now a truss almost rigid for any pull or weight coming on it less than eight pounds. If there is any deflection it will be so much below the quantity allowed in good con-

struction, which is the $\frac{1}{1500}$ of the span, that practically it will not amount to anything. I can increase considerably the rigidity of the truss with a wire having its ends fastened in *A* and *B* and passing under wire *C E D* supporting the apex *E* and resisting its deflection when the load comes on the centre of the span. Let you suppose now the fixed points to be bolts put through posts, the posts 10 feet apart from centre to centre and the deflection of the wire 2 feet. Suppose a whole line of posts put 10 feet apart from centre to centre and supporting one line or two parallel lines of light iron or steel rails or of T iron, the centre of those rails or T iron acting as such, being supported in the centre of the span of 10 feet by the rigid truss and you will have an idea of my elevated railroad. Half of the weight carried on the span by those rails will go on their centre and by means of short vertical posts will come on the truss. In my railroad the span of 10 feet

Fig. 1.

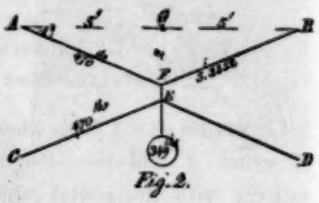


Fig. 2.

affords room for two small cars 4 feet long each and consequently the weight coming on the centre of the rail and which has to be supported by the truss is the weight of one car loaded. If the top wires, by means of an iron rod and nuts, have been braced in advance with the bottom wires, to a rigidity equal to the one they would get with the weight of one loaded car suspended to them, they will be kept to that rigidity or tension by the lower wires having the same tension with the same deflection, and when the weight of the loaded car will come on the centre of the rail, the effort causing that rail to deflect will be only half of that weight, because as soon as the loaded car presses on the top wires of the truss, the bottom wires are relieved and have a tendency to contract, their action on the top wires ceasing. Between those two actions, the weight pressing on them from the top and the lower wires ceasing to press on them, the top wires will deflect half the quantity they would if there was no truss and the loaded car was suspended to them. Consequently if in moderate weather, at a temperature I suppose of 45° Fahrenheit, the trusses have the required

rigidity for not deflecting more than $\frac{1}{1500}$ of the span or 0·08 inch when the weight of one loaded car comes on them, it is only at an elevated temperature of 120° Fahrenheit, for example, that the deflection may increase in a way worth to be observed and attended to. We are going to find what will be the increase of deflection and the way to keep it in proper limits. Let us examine in a general way the effects of variations of temperature upon the truss. Suppose we have a Bessemer steel wire No. 6 of the gauge of the Trenton Iron Co. It has a diameter of 0·190 inch and this commonly in the market will break under a pull of 2,875 pounds.

Suppose we have a truss *A, F, B, C, E, D,* made with such wire. (Fig. 2.)

The distance between the fixed points *A* and *B* is 10 feet, and the deflection of the wire 2 feet or $\frac{1}{5}$. Let us suppose that at a moderate temperature of 45° Fahrenheit, it has been found that the deflection 2

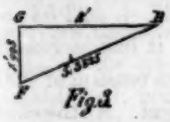


Fig. 3.

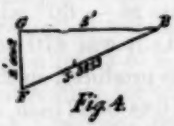


Fig. 4.

Fig. 5.

feet takes place when a weight of 349 pounds is suspended in *F* to the top wire. Then the tension on the wire is found by the formula

$$\frac{Wl}{4d}\text{Sec. }\varphi = \text{Tension, or } \frac{349 \times 10}{8} \times \frac{5{\cdot}3852}{5} = 470, \text{ to be 470 lbs.}$$

Suppose now that a decrease of 75° takes place in the temperature, the thermometer falling to 30° below zero. Let us consider the top wire *A, F, B.* If it was free to contract, if it was not prevented by the lower wires, and if the weight 349 pounds was suspended to it, it would contract, raising that weight with it. As a steel wire, according to Faraday, expands or contracts 0·00000661 of its length for every change of 1° in the temperature, it would contract 0·0641 inch and its length instead of being 10·7704 feet, as it is at 45°, would be 10·7651 feet, and the deflection of the wire would have become 1·993 feet. (Fig. 3.)

With this new deflection the tension of the wire with the weight suspended to it would be 471·27 pounds. But when the truss is formed, the top wire is not free to contract and take a smaller deflection. The bracing rod *E F* prevents it. On the contrary, that rod itself has a tendency to contract by the cold and this has to be taken into account.

Let us see first what will be the contraction of the rod for 75 degrees fall in the temperature. Iron expands or contracts 0·00000698 of its length for 1° change in the temperature. Let the rod be 9 inches long and $\frac{1}{2}$ inch diameter. For 75° fall in temperature it will contract 0·00039 feet and become 0·7496 feet long. This would increase the deflection of the wire by 0·000195 feet at each end of the rod, so that at 30° below zero the deflection of the wire would be 2·0002 feet. The increase of tension of the wire in the truss at 30° below zero would be then precisely the increase of tension it would have if from the deflection 1·993 feet and the corresponding tension 471·27 found before, it it was brought by forcible pulling to the deflection 2·0002 feet. With deflection 1·993 feet the length of the wire is 10·765 and with deflection 2·0002 feet its length is 10·7706 feet. (Fig. 4.) It would consequently extend 0·0056 feet or 0·0672 inches. Then the increase of tension can be calculated and is $\frac{0{\cdot}0336}{5{\cdot}3825 \times 12} \times 35500000 \times 0{\cdot}02835 = 523{\cdot}54$ lbs. Then the wire of the truss at — 30° will have 471·27 + 523·54 = 994·81 pounds tension. As it was 470 pounds at 45° it has increased 524·81 pounds, and this has produced on the rod an extra tension of 390 pounds, causing it to extend 0·000666 inch, or 0·000055 feet. As the cold has a tendency to contract it 0·00039 feet, it will finally contract 0·00034 feet or 0·00017 feet at each end. The deflection will become 2·0026 feet, and the extra tension of the wire will be 523·54 pounds. Then the wire at — 30° will have 995 pounds tension, having yet a safety of $\frac{2875}{995} = 2{\cdot}88$, say 3, which is quite sufficient for wire. The limit of elasticity of that wire is between 1,438 pounds and 1,916 pounds, and the danger of its being broken is only when the tension approaches that limit of elasticity.

I will now show that at a moderate temperature of 45°, if there was no truss, and if the top wire had a deflection of 2 feet with the weight 349 pounds suspended to it, that wire would contract so as to have only 1·993 feet of the deflection if the weight was taken off. Because that weight gives the wire 470 pounds tension stretching it 0·06033 inch, or 0·0053 feet. Consequently that weight of 349 pounds suspended to the wire has brought it from the length 10·7650 feet to the length 10·7704 feet, increasing its deflection from 1·993 feet to 2 feet, or 0·007 feet, or 0·084 inch. And when the truss is formed in the conditions said above, if the weight 349 pounds be sus-

pended to the truss or presses on it, the deflection will be only 0·042 inch, or 0·00035 of the span, instead of 0·00066 allowed in good construction.

Let us see now what takes place when the temperature increases. For 75° increase of temperature the wire, which is 10·7704 feet long at 45°, will increase 0·000496 of the length, or 0·0053 feet. It will become 10·7757 feet long, the weight 349 pounds pressing on it. This corresponds to a deflection of 2·007 feet. (Fig. 5.) Under that deflection the tension of the wire, under the load 349 pounds suspended to it, will be 468½ pounds. The deflection 0·007 feet is equal to 0·084 inch, or the deflection allowed in the beam, which is 0·08 inch, or the $\frac{1}{1500}$ of the span. Consequently the deflection of the rails worth noticing will only take place in very hot weather, and at 120° it will not exceed 0·08 inch, or the $\frac{1}{1500}$ of the span. The preceding calculations show that a safety $\frac{2875}{470} = 6$ is sufficient to allow the wires to resist their greatest tension in the extreme cold weather with a safety of 3 and to prevent them having in extreme hot weather a deflection greater than $\frac{1}{1500}$ of the span. With such a safety of 6, the elevated railroad, once established, need be regulated neither for cold or hot weather; but for bridges it is different, because you have then to use wire cables, more expensive than single wires. I intend building bridges on the system of my truss with safety of only 3, and to regulate them by hand, or have them regulate themselves, for all changes of temperature.

We have seen that for a span of 10 feet a wire No. 6, with a deflection of 2 feet, braced with another wire of same number, same length and same deflection, will form a truss which at all temperatures will support safely the weight of 349 pounds pressing on it. Suppose, now, that we have four such wires, No. 6, two on one side of the posts and two on the other side, passing over the same bolts through the posts, and braced with four lower wires, of same number, length and deflection, and we will have a truss formed with eight wires, which will support safely at all temperatures a weight equal to four times 349, or 1,396 pounds, and in supposing the rail used to be an iron one, weighing 16 pounds to the yard, or 54 pounds for the span of 10 feet, only the half of the weight of that rail, or 27 pounds, would have to be deducted from 1,396 pounds to get the moving weight, 1,369 pounds, that such a truss would support safely on its centre. An elevated railroad built with such a truss would support, then, safely, at all temperatures, a train formed of small cars, 4 feet long,

weighing each, loaded, 1,369 pounds; and, as each of those small cars, empty, would weigh about 250 pounds, they could be each loaded with 1,120 pounds, or $\frac{1}{2}$ ton of ore. A train of 40 of these small cars would be 200 feet long, and would carry 20 tons of ore, and the expense to build such an elevated railroad would be, on uniform ground, less than $3,500 a mile. Let two such trains, containing each 20 tons, be run in one hour from the mine to the mill or to the shipping point, and 400 tons will be transported in a day of 10 hours.

I will now explain why I make the spans only 10 feet instead of 20 feet or more. It is because, by so doing, I get tensions which allow me to use isolated wires costing five times less for same weight than a rope of equal strength. For example, we have seen that on a span of 10 feet, with wire No. 6, having a deflection of 2 feet, I can run safely two cars weighing each, loaded, 1,369 pounds, the truss supporting, besides, the weight of the rail. On such a structure the posts are 3 inches square, and their top is 5 feet above the ground. What would take place if the span was 20 feet instead of 10 feet? (Fig. 6.) The weight supported by the truss at its centre will be then the weight

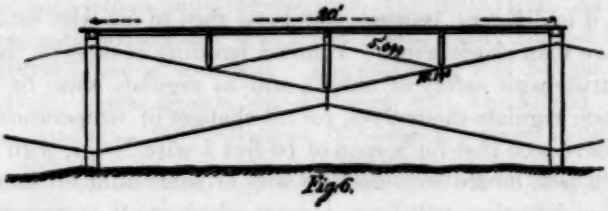


Fig. 6.

of two loaded cars, 2,738 pounds + 54 pounds, half the weight of the rail, total 2,792 pounds; and, if I do not want to increase the expense of the posts by increasing their length and size, in order to keep a deflection of $\frac{1}{5}$, I shall have to keep the same deflection, 2 feet, I had before, and have $\frac{1}{10}$ deflection. This increase of span, of weight and that decrease of deflection, is going to make the tension on the wire nearly four times greater than it was before; for it will be now 1,780 pounds on each of the four top wires, and the same on the lower ones, when it was before only 470 pounds on each. To have a safety of 6, each of the wires of the 20 feet span must not break under a pull less than 1,780 × 6, or 10,680 pounds. We come then to an extra size of wire, for wire No. 0, Birmingham gauge, breaks under a pull of

8,999 pounds, and we have to use steel rope. We would have to get 8 of them, of ½ inch diameter. That would be a length of 163 feet of ½-inch rope, costing $22 and weighing 57 pounds, while with two spans of 10 feet I have only 172 feet of No. 6 wire, Trenton Iron Co. gauge, weighing 16½ pounds and costing 87 cents. It takes 10·44 feet of No. 6 wire to weigh one pound, and it costs $5\frac{3}{16}$ cents per pound; while ½ inch rope costs 15 cents per foot, or 13½ cents with discount of 10 per cent., and weighs 0·35 pound per foot. Furthermore, if I want to use the same 16-pound rail on the 20-foot span, I have to support it every five feet, and this will necessitate an additional length of rope equal to 21 feet and costing $2.84, bringing the total cost of rope to $24.84, while the No. 6 wire cost only 87 cents. If it is considered that the post economized by the 20-foot span cost only 20 cents, with the five holes drilled in it, it will appear at once how it is cheaper to have 10-foot spans instead of longer spans. The increase of length of span and the use of ropes makes the cost twenty times

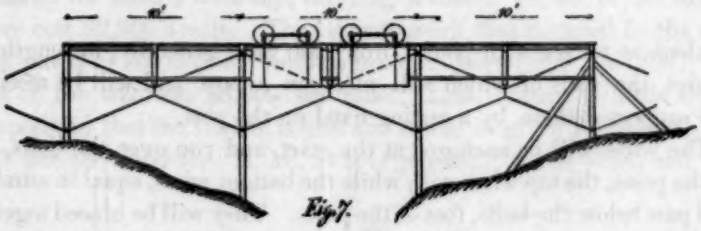


Fig. 7.

greater, and the advantages of my invention in using wires instead of wire ropes or cables, unless compelled to do it, and in reducing the spans to 10 feet, are self-evident.

I will now give a brief description of my elevated railroad or tramway applied to mines. (Fig. 7.) It is built with only one line of posts, generally 3 inches square and 7 feet long. They go 1½ feet in the ground, and their top is consequently 5½ feet above the ground. They are put 10 feet apart, from centre to centre, as I said before, and are braced at their bottom part by 2 braces, whose tops are joined to the posts by a bolt, and whose feet rest in slots cut in a plank, 2 feet long, 9 inches wide and 2 inches thick, which has a rectangular hole cut in it, through which passes the post. (Figs. 8 and 9.) This not only braces the post, but brings on the surface of ground covered by the plank the whole weight coming on the post. The posts are made besides perfectly

steady by wires fastened to them, and also to stakes driven hard in the ground, or to rock; and every fifty feet they are braced in the direction of the road. This line of posts will support, according to circumstances and wishes, either one single rail or two or three rails. I will give a description of the tramway with only one rail.

Fig. 10.

Fig. 8.

Fig. 9.

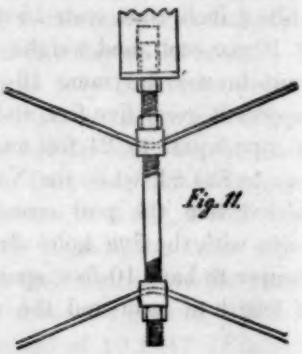


Fig. 11.

I calculate to use a 16-pound iron rail, most generally, in lengths of 20 feet, the ends of which will meet on a post and will be received and supported there by a casting fixed on the post.

The wires will be anchored at the start, and run over the bolts, top of the posts, the top wires will, while the bottom wires, equal in number, will pass below the bolts, foot of the posts. They will be braced together in the centre of the spans by an iron rod, with 3 nuts and two small

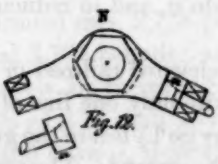


Fig. 12.

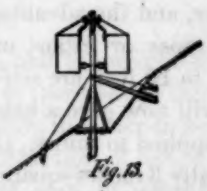


Fig. 13.

castings called wire pressers. Fig. 10 and Fig. 11.) Their deflection, calculated in advance, and which is 2 feet, and a loaded car run on the centre of each span, will indicate how they are to be braced. The wire can be run in lengths of 500 feet, 1,000 feet, or even one mile before being stopped. Where it is stopped the end of the wire is riveted in a small piece *m*, of steel casting, and held in another piece *N*, of steel casting, fixed on the bolts crossing the posts. (Fig. 12.) That piece holds the ends

of the wires stopped, and also those of the new wires. The rails are supported in centre of the span by a casting fixed on a short post, whose end has fixed on it a cast iron washer, resting on the top nut of the bracing rod. That bracing rod goes itself two inches in the post, which has a hole drilled in it to receive it. When the loaded car comes to the centre of the span, its weight presses on the top nut of the bracing rod and through it goes on the truss which receives it. That top nut allows also to give the rail a slight camber. The

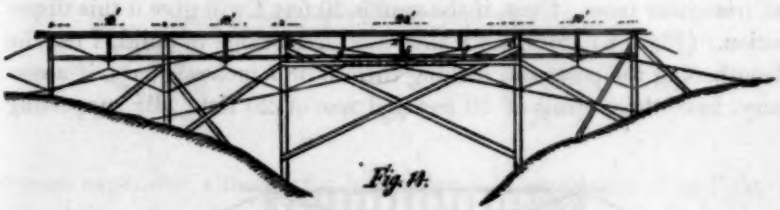


Fig. 11.

material for such a tramway, carrying trains of 10, 20, or 30 tons or more cost $2,000 a mile. The labor to work that material in the shop and put it in the field on uniform ground, cost $1,000 per mile; total cost of the tramway $3,000 per mile. This estimate is made with a supposition that the timber, sound and sawed to given dimensions, cost $30 per thousand feet, B. M., as it is generally in the West, and that

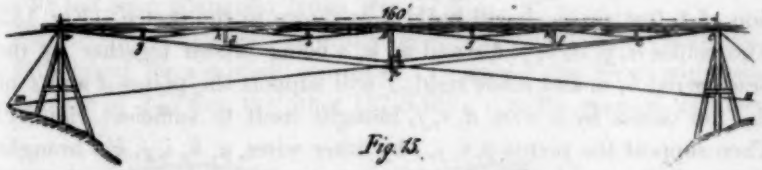


Fig. 13.

the iron, cast iron and labor cost as they generally do in Philadelphia. In places where the prices are such, I offer to furnish the material per mile, and put it up for $4,000 per mile. The small cars, holding a half ton each, will cost $25 each, and if the railroad runs by gravity, the cost of the rope, sheaves and machinery has to be added. That cost would be about $600 to $800.

The form of the cars is as shown in Fig. 13. They are formed with two boxes, hanging below the wheels, and 4 feet long, 16 inches wide, and 2 feet and 3 inches high. Each box has in its bottom part and

in its middle a small cast iron wheel, 5 inches diameter, running on a piece of *T* iron fixed on the posts. The diameter of the car wheels is 12 inches, and each car has only two wheels. They empty by the movable bottom. This elevated railroad is principally advantageous in countries where the ground is a little rolling or broken, because with it the grading can be saved. It is also very economical when the railroad has to run along a side hill, because I save the whole of the grading necessary with an ordinary railroad.

I will now explain how I would build a bridge with that same system of triangular truss. First, if the span is 20 feet I will give it this disposition. (Fig. 14.) Suppose I have a 50 feet bridge to build, I can, by lengthening the posts and making them 6 or 7 inches square, if necessary, have three spans of 10 feet and one of 20 feet. By supporting

Fig.16.

the points *d* and *f* of the wire *a*, *d*, *b*, *f*, *c*, by another wire *d*, *e*, *f*, and putting two small posts in *d* and *f*, the rail will be supported every 5 feet the same as in the 10 feet span.

If I have to build a bridge 160 feet long in one span, with a deflection of 8 feet, or $\frac{1}{20}$, I will build it as shown in the sketch. (Fig. 15.) The cables *a*, *g*, *d*, *b*, *f*, *l*, *c* and *m*, *n*, *o* being braced together by the bracing rod *b*, *n*, and made rigid, I will support the points *d* and *f* of the top cables by a wire *d*, *e*, *f*, brought itself to sufficient rigidity. Then support the points *g*, *i*, *j*, *l* by other wires, *g*, *h*, *i*, *j*, *k*, *l* brought also to sufficient rigidity, and so on, so as to support the rail every 5 feet, as in the span of 10 feet, or every $2\frac{1}{2}$ feet, if necessary. Bridges of 1,000 feet spans can be built very cheap, light and strong on this plan. In adding to the bridge the cable *a*, *p*, *c*, of same diameter as cable *a*, *b*, *c*, and pressed by a wire presser and a nut on the prolongation of bracing rod *b*, *n*, I will reduce still more the deflection in a very large proportion, and by means of a couple of springs on the rod *b*, *n*, the bridge will regulate itself at all temperatures.

Another bridge could be built with two cables, having the parabolic form and in an inverted position (Fig. 16), as was suggested by Mr.

Leblanc, a French chief engineer of road and bridges, but to make such a bridge perfectly rigid it would be necessary to brace it as shown on the sketch, and then it would be more expensive than the one I designed with the triangular truss of my invention.

The system proposed by Mr. Leblanc of two cables of a parabolic form in an inverted position, and braced together at regular intervals by vertical rods, would not, in my opinion offer sufficient rigidity. I improved it in bracing the truss, as shown on the sketch, but it makes

Fig. 17.

it more expensive, although for long spans it is, on account of its lightness, cheaper than the ordinary truss bridge. Such a suspension bridge would have all the rigidity necessary to allow a train of cars to pass over it, and would have but very little deflection. I prefer, however, the triangular truss, thinking it cheaper. (Fig. 18.)

I will conclude, saying that in the triangular truss one set of cables might be in the position *A*, *B*, *C*, and the other set in position *D*, *E*, *F*, the cables being braced together top and bottom of post *E*, *B*. This might be advantageous in some cases. This disposition applies also to the 10 feet span triangular truss. Fig. 17.)

Fig. 18 shows a suspension bridge (system Leblanc) improved by me, and designed for a mining company. It crosses the river with two spans, one of 275 feet, the other 137·5 feet. On the span of 275 feet

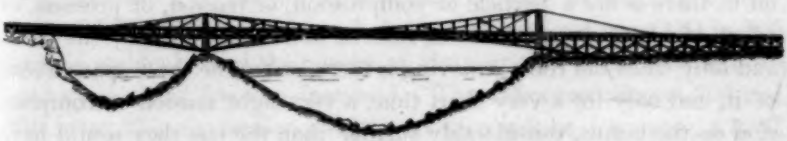


Fig. 18.

it is able to support, besides its own weight, 56 cars weighing each, loaded, 1400 lbs. Total 78,400 lbs. of moving load, which will not give the bridge over two inches deflection. Deflection $\frac{1}{240}$. The bridge supports on its own length 52½ tons of moving load. There are four

top cables 2¾ inches diameter, and four lower cables 1⅞ inch diameter. The superstructure of the 275 feet span weighs 64,095 lbs.

The total cost of the suspension bridge 412½ feet long, including towers and masonry for anchoring is $12,000.

Philadelphia, June 7, 1884.

DISCUSSION.

MR. HUGO BILGRAM:—I can see that the addition of the lower chord reduces the amount of inflection due to a certain change of load, but I fail to see that this truss is any stronger than the same truss minus the lower chord, *i. e.*, I do not see how the addition of the lower wires contribute to the ultimate strength of the truss.

MR. QUETIL:—In reply to the question of Mr. Bilgram, if the truss would not be just as good without the lower wires, and bracing simply the top wires in the ordinary way, I answer in the negative. The question is equivalent to asking me if my truss presents any advantage over the ordinary triangular truss. This I can answer affirmatively. Evidently the gentleman does not see that the great advantage of my truss, besides the one it has of reducing the deflections more than the ordinary truss can do, is to offer to the rails, or beams under them, a support, without fatiguing them by a compression at their ends and a pressure at their centre, as is the case with the ordinary way of bracing them, a way so singular that the more you screw the nuts at the ends of the rods, trying to make the beam stronger, the more you approach the final result, which will be to break it if you persist in making it stronger. When the elevated railroad, formed with my truss, has no train moving on it, there is not a particle of compression, or tension, or pression, or effort, of whatever nature on the rails or beams supported by the posts, and only when the train is moving is there, on two or three spans ahead of it, and only for a very short time, a very light tension or compression on the beams, considerably smaller than the one they would have if they were braced the ordinary way. This I am going to prove, and this reduction in the compression allows me to use material considerably lighter than with the ordinary way.

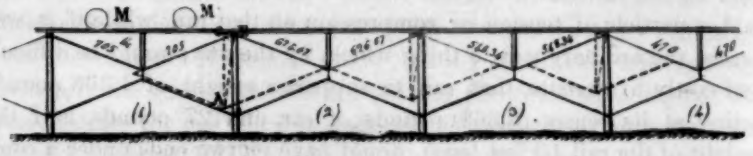
I have demonstrated with a model, at the meeting, that, if I form the truss with No. 23 wire, so that on a span 10 inches long and under a weight of 12 pounds suspended to both, or 6 pounds to each of them,

the top wires, two in number, have a deflection of 2·0625 inches, which gives each of them a tension of 8 pounds, and if, when once the truss is formed with the lower wires of same number and same deflection, I suspend again the weight 12 pounds to the truss, the tension on the top wires will only be the one, that a weight of 9 pounds suspended to each of them would give them and not a tension that a weight of 12 pounds suspended to each of them would give them, as the majority of people seem to think. The tension on each wire, which was 8, will become then 12 pounds, and not 16 pounds.

Let us suppose now the spans to be 10 feet and the deflection of the wire two feet, and that the truss on the different spans of the railroad is made with No. 6 wire, Trenton Iron Co. gauge, and that the moving load is a train formed of cars weighing 1,369 pounds each, a span of 10 feet giving room to two of these cars, and let us suppose the rail supported by the posts to be a 16-pound iron rail supported or not by beams. The centre of that rail is supported by the truss. On that part of the railroad where the train is not moving, there is not, as I said, a particle of tension or compression on that rail, while if it was braced the ordinary way, a thing which, by the way, would be difficult and costly to execute, that rail to support a weight of 1,396 pounds acting at its centre (3,369 pounds of car, and 27 pounds, half the weight of the rail 10 feet long), would have its two ends under a compression of 1,745 pounds, given by the bracing rods or wires fixed at its ends. Let us see now what will take place when the train is moving. First, let us state that in the parts where the train does not move, all the wires are under a tension of 470 pounds each, the temperature being supposed to be 45°F. Now when the first car of the train comes on a new span and when it has traveled the three-quarters of it, the tension of the top wires in that span has increased gradually from 626·67 to 705 pounds, as I shall prove, and not from 470 to 705 pounds, suddenly, and the tension of the top wires in the two or three next spans ahead has also increased. The difference between 705 and 470 being 235, the tension on the next span will be, I suppose, 626·67 pounds; on the following span 548·34, and on the third span 470 pounds, the same as on the other spans ahead. On the railroad which I have built, full size, in Philadelphia, for experimenting, I found that it is so. That as the loaded car moves on it, the change in the tensions extends only a couple of spans ahead of the car.

It is a great mistake to think that if the tension of the top wires is

705 pounds in span (1) when the two cars *M* and *M'* are on it, the tension will stay at 470 pounds in span (2). I know the contrary, because I have seen that when the weight came on span (1), the beam of span (2) rose a little, and also that of span (3), although of a smaller quantity, and that in span (4) the beam did not rise, which shows, as I have said before, that the increase of tension communicates itself gradually to the wires of the spans ahead of the train, the effect being produced on only two or three spans the most. For example, when the cars will be in span (1), the tension of the top wires in span (3) will pass from 470 pounds to 548·33 pounds. Then when the cars will be in span (2), the tension of the wires in span (3) will pass from 548·34 pounds to 626·67 pounds, and finally, when the cars will be in span (3) the tension of the wires in span (3) will pass from 626·67 to 705 pounds. Now when on the bolt top of post B, the tension is one side 705 pounds, and 626·67 pounds on the other, the resultant of these two inequal tensions is in the direction *AB* and has an horizontal



component *BC* equal to 70 pounds; four times this, is 280 pounds. This would be all the compression that would take place on the end of the beam or rail in span (1) if, by a circumstance which will never happen, the span (2) and others ahead were going to vanish suddenly when the first car of the train is in position *M'*. The beams or rails will never be compressed with 280 pounds, because their ends are held by castings fixed on the posts. The posts will not move because they are braced solidly every fifty feet in the direction of the railroad, and all the way through by the rails or beams at their top, and as the effort is on the posts, if they have no motion, the rails or beams will not have any either, and consequently there will be no effort on them. There cannot be any compression without a tension on the next rail. The worst that may happen is that the effort of 280 pounds divides itself in two, or of 140 pounds compression on the end of rail in span (1), and the other of 140 pounds tension on the end of rail in span (2). Consequently I will never get more than 140 pounds compression on the top chord or rail of my truss, or *twelve and a half times less than if*

the rails were braced the ordinary way. This is one of the advantages of my truss, and I hope that those who could not see it, will see it now.

This would allow me, on a railroad built for a large traffic, in a trestle bridge with spans of 30 feet, made with two parallel trusses supporting each 1 ton of movable load per lineal foot, and braced in one case, the ordinary one, with iron rods $2\frac{1}{8}$ inches diameter, and in the other case, that is to say, with my truss, with cables $1\frac{5}{16}$ inches diameter, the deflection being $\frac{1}{8}$ of the span, to use for such spans only 2 beams $12'' \times 20''$ each instead of 4 beams $8'' \times 20''$, which would have to be used the ordinary way, on account of the compression, 33,600 pounds, under which each of those four beams would be if they were braced the ordinary way. I would have thus an economy of 1,600 pounds of timber costing $16 in one span only, which would allow me to build the bridge cheaper with my truss, and I call the attention of railroad engineers to this. I have made comparative estimates and know that it is so.

The economy with my truss is, per span of 30 feet, one ton and a half of beams, bolsters, and other materials, representing $45 in the cost of material, without counting the labor. Then my truss is stronger than the ordinary truss.

THE NEW BRITISH STANDARD WIRE GAUGE.

The makers of wire and sheet metals have, from time immemorial, designated the various sizes, diameters or thicknesses of their productions by a series of numbers; but the actual size represented by each of these numbers has had no universally accepted value. A multiplicity of so-called standards or gauges have been in existence, and endless confusion and trouble has been the result. Not only do the various standards vary, but different specimens of the same standard, even when made by the same maker, fail to agree together with the accuracy demanded by modern needs.

That which has undoubtedly the greatest currency is known as the Birmingham Wire Gauge, and can be traced back at least as far as the early part of the last century. It consists of a plate having in its edges a series of notches, each marked by a number indicating the thickness of the corresponding plate or wire. These notches have been added or altered as circumstances seemed to require, and together they form a series of sizes in some manner roughly proportionate to one another.

Many attempts have been made to harmonize the existing differences, so as to insure uniformity of size and a regular proportion—geometrical or empirical—between the various sizes.

To insure this uniformity of size, it has been repeatedly suggested that the whole difficulty could be obviated by expressing the sizes in thousandths of an inch. This was the conclusion reached by a Committee of the *American Institute of Mining Engineers*, whose "Report on a Standard Wire Gauge" was published in this JOURNAL, for February, 1878, and who recommended the micrometer screw caliper as the best known form of measuring device for this purpose. They did not, however, propose any series of sizes which would meet all requirements. For convenience, such a series of sizes must be agreed upon, and these sizes should bear some proportionate relation to one another: it is generally thought that the components of such a series could be most conveniently distinguished in trade by their numbers.

Many such series have been designed, but none of them have secured a universal recognition. Thus, the late Robert Briggs, C. E., proposed a gauge in which the reduction from one size to another should be 10 per cent. in diameter, or 19 per cent. in weight, starting with No. 0 = 1 centimetre. Mr. Latimer Clark proposed a series with the same starting-point, but with a reduction of 20 per cent. in weight and 10·557 per cent. in diameter.

In Great Britain the subject has long been discussed, and has of late received a new impetus from the manufacturers of electrical apparatus, to whom the size of the wire employed is often a vital matter. The feeling in England seems to have been that no gauge differing widely from the Birmingham gauge could be successfully introduced, and many attempts have been made to ascertain the exact sizes of the various numbers, and to modify them slightly, so as to bring the series of numbers up to modern requirements without entirely subverting present practice. This effort has finally culminated in the adoption by the *Standard* Department of the Board of Trade of Great Britain of a New Legal Standard Wire Gauge, which fixes a definite value for each number of the Birmingham Gauge.

Through the courtesy of Prof. J. E. Hilgard, Superintendent of the U. S. Coast and Geodetic Survey, we are enabled to present herewith official tables giving the New Standards in millimetres and in parts of an inch. Professor Hilgard has also favored us with a series of interesting analyses of the new and old gauges, which we are glad to have an opportunity of putting on record.

NEW LEGAL STANDARD WIRE GAUGE.

Descriptive Number. B. W. G.	Equivalent in parts of an inch.	Descriptive Number. B. W. G.	Equivalent in parts of an inch.
No. 7/0	0·500	No. 23	0·024
6/0	464	24	22
5/0	432	25	20
4/0	400	26	18
3/0	372	27	0164
2/0	348	28	148
0	324	29	136
1	300	30	124
2	276	31	116
3	252	32	108
4	232	33	100
5	212	34	0092
6	192	35	84
7	176	36	76
8	160	37	68
9	144	38	60
10	128	39	52
11	116	40	48
12	104	41	44
13	92	42	40
14	80	43	36
15	72	44	32
16	64	45	28
17	56	46	24
18	48	47	20
19	40	48	16
20	36	49	12
21	32	50	0010
22	28		

11,867.—500.—2/84. Wt. 2,3838. E. & S.

NEW LEGAL STANDARD WIRE GAUGE.

Descriptive Number. B. W. G.	Metric equivalent in millimetres.	Descriptive Number. B. W. G.	Metric equivalent in millimetres.
	m.m.		m.m.
No. 7/0	12·700	No. 23	0·610
6/0	11·785	24	0·559
5/0	10·973	25	0·508
4/0	10·160	26	0·457
3/0	9·449	27	0·4166
2/0	8·839	28	0·3759
0	8·229	29	0·3454
1	7·620	30	0·3150
2	7·010	31	0·2946
3	6·401	32	0·2743
4	5·893	33	0·2540
5	5·385	34	0·2337
6	4·877	35	0·2134
7	4·470	36	0·1930
8	4·064	37	0·1727
9	3·658	38	0·1524
10	3·251	39	0·1321
11	2·946	40	0·1219
12	2·642	41	0·1118
13	2·337	42	0·1016
14	2·032	43	0·0914
15	1·829	44	0·0813
16	1·626	45	0·0711
17	1·422	46	0·0610
18	1·219	47	0·0508
19	1·016	48	0·0406
20	0·914	49	0·0305
21	0·813	50	0·0254
22	0·711		

The table below presents the values that have been adopted by Act of Parliament for the new British Legal Standard Wire Gauge.

Descriptive Number. B. W. G.	Equivalent in parts of an inch.	Differences.	Descriptive Number. B. W. G.	Equivalent in parts of an inch.	Differences.
No. 7/0	0·500	0·036	No. 23	0·024	0·002
6/0	464	32	24	22	2
5/0	432	32	25	20	2
4/0	400	28	26	18	16
3/0	372	24	27	164	16
2/0	348	24	28	148	12
0	324	24	29	136	12
1	300	24	30	124	8
2	276	24	31	116	8
3	252	20	32	108	8
4	232	20	33	100	8
5	212	20	34	92	8
6	192	16	35	84	8
7	176	16	36	76	8
8	160	16	37	68	8
9	144	16	38	60	8
10	128	12	39	52	4
11	116	12	40	48	4
12	104	12	41	44	4
13	92	12	42	40	4
14	80	08	43	36	4
15	72	8	44	32	4
16	64	8	45	28	4
17	56	8	46	24	4
18	48	8	47	20	4
19	40	4	48	16	4
20	36	4	49	12	2
21	32	4	50	10	
22	28	4			

It will appear at first glance that this is the Birmingham or Stubs' gauge, considerably simplified. In that the numbers representing the different sizes are in a majority of cases prime to each other, and simple exact ratios impossible. In the new gauge all the numbers, as given in the table, with three exceptions, are multiples of 4, and it is

possible for one gauge to be exactly double some other. This occurs in nineteen cases, beginning with Nos. 6|0 and 4 and ending with Nos. 47 and 50. There is, of course, an approximation to this ratio in many other cases, but the limitations of the problem seem to prevent a greater number of exact agreements.

The figures in the third column of the table show how much less each following number is than the preceding. Here also there is a progession by 4s (with the exceptions noted above), though the number of times that each number enters is governed by no law, 36 entering once, and 8 fourteen times.

Descriptive No.	New Leg. Std.	Birmingham.	D. B. & S.	Descriptive No.	New Leg. Std.	Birmingham.	D. B. & S.
0000000	0·500			23	0·024	0·025	0·22571
000000	464			24	22	22	201
00000	432			25	20	20	179
0000	400	0·454	0·46	26	18	18	1594
000	372	425	40964	27	164	16	14195
00	348	380	3648	28	148	14	12641
0	324	340	32495	29	136	13	11257
1	300	300	2893	30	124	12	10025
2	276	284	25763	31	116	10	8928
3	252	259	22942	32	108	9	795
4	232	238	20431	33	100	8	708
5	212	220	18194	34	92	7	6304
6	192	203	16202	35	84	5	5614
7	176	180	14428	36	76	4	5
8	160	165	12849	37	68	.....	4453
9	144	148	11443	38	60	.....	3965
10	128	134	10189	39	52	.....	3531
11	116	120	90742	40	48	.....	3144
12	104	109	80808	41	44		
13	92	95	71961	42	40		
14	80	83	64084	43	36		
15	72	72	57068	44	32		
16	64	65	5082	45	28		
17	56	58	45257	46	24		
18	48	49	40303	47	20		
19	40	42	3589	48	16		
20	36	35	31961	49	12		
21	32	32	28462	50	10		
22	28	28	25347				

Above are placed, side by side, the new scale, the Birmingham* scale and the Darling, Brown & Sharpe scale, the values being given in fractions of an inch.

By comparison of the first two scales it will be seen that for the old series of four sizes from 0000 to 0 is substituted a series of seven sizes from 0000000 to 0, the first lying entirely outside the old series, and being exactly $\frac{1}{2}$ inch. At No. 1 there is agreement between the two scales, the value being 0·3 inch. From this point to No. 30 there is substantial agreement. The six sizes following No. 30 in the old series range from 0·1 to 0·004. To these correspond twelve sizes in the new. The last eight numbers in the new series have no counterpart in the old.

INFLUENCE OF HIGH PRESSURES ON LIVING ORGANISMS—The recent expedition of the *Talisman* has furnished interesting proofs of the existence of organic life at great depths in the sea. Direct experiments have been made by M. Regnard, with the press of Messrs. Cailletet and Ducretet, by which a pressure of more than a thousand atmospheres can be obtained, corresponding to a depth of water of more than 10 kilometres (6,214 miles). Beer-yeast, when submitted to the pressure of a thousand atmospheres for an hour, and then placed in contact with sweetened water, appeared to be latent. After about an hour it revived, when fermentation began and went on slowly. Yeast was afterwards left in sweetened water, under a pressure of 696 atmospheres for seven hours, when no fermentation took place. The tube was then withdrawn and, after an hour, fermentation began. Under the pressure of a thousand atmospheres, starch was transformed into sugar by saliva. Algæ, when submitted to six hundred atmospheres, for an hour, were able to decompose carbonic acid under solar influence; but four days afterwards they were dead and began to putrefy. Seeds of cress, after ten minutes exposure under a thousand atmospheres, were swollen with water, and it was a week before they began to sprout. Stagnant water, swarming with infusoria, was subjected to six hundred atmospheres. After a half-hour's exposure the animals seemed to be asleep, but after they were withdrawn, they soon revived. Molusca, bloodsuckers, and crustacea, though apparently asleep or dead under the pressure, revived more or less rapidly after being withdrawn. Fishes, without a swimming-bladder, can be subjected with impunity to the pressure of a hundred atmospheres. At two hundred atmospheres they seem to be asleep but may be quickly revived. At three hundred atmospheres they die. At four hundred atmospheres or more they are dead and rigid; they putrify even without losing their rigidity.—*Chron. Industr.*, April 6, 1884. C.

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* The values for the Birmingham scale here given are those which were determined in 1846 by Mr. Holtzapffel, who examined the best specimens of the gauge then obtainable. These values have been widely adopted, although they differ more or less from the figures given by other and more recent authorities.

REPORT ON THE TRIAL OF THE "CITY OF FALL RIVER."

By J. E. Sague, M. E., and J. B. Adger, M. E., with an introduction by Professor R. H. Thurston.

(Continued from Vol. cxviii., page 74.)

The reaction of the stream of water acted upon by any propelling instrument, equals the product of the mass of a cubic foot of water, the number of cubic feet of water acted upon in a second, and the velocity in feet per second impressed upon that water by the propeller. This reaction equals the total forward thrust on the paddle shaft. In the case of a propeller working in a current previously induced by the ship in its own direction, technically known as the following current, and owing to "skin" friction or otherwise, there is a loss of thrust owing to the increased flow caused by the propeller; and a mathematical investigation proves this to be always a source of waste power.

The following current though affecting greatly the working of screws placed at the stern, probably does not act to any appreciable extent upon a paddle placed as far forward as the one under consideration; and, as there is also no way of determining the velocity of such a current beyond a rough approximation, it is neglected here, as well as by Rankine in his examples from paddle steamers. Letting T = total thrust = effective thrust in case of no forward current.

u = velocity of ship = velocity of water relatively to ship in the absence of the propeller.

v = actual backward velocity of water with reference to ship.

a = area of stream driven back by propeller.

$\frac{w}{g}$ = mass of 1 cubic foot of sea-water = 2 nearly.

Volume of water acted upon = $v \times a$;

Velocity impressed by propeller = $v - u$;

$$T = \frac{w}{g} v(v - u)a.$$

To apply this general formula to feathering wheels let r' = radius to centre of pressure. n = revolutions per second. $2\pi nr'$ = velocities of centres of pressure of floats relativeiy to ship, which = v; as with feathering floats the velocity of stream driven aft = velocity of floats

themselves. Let $2\pi nr_0$ = velocity of ship, then r_0 is the radius of apparent rolling circle; and since we have neglected the forward current, it is also the radius of the real rolling circle.

$2\pi n(r' - r_0)$ = slip of paddles = $(v - u)$.

Then $T = \frac{w}{g} 4\pi^2 n^2 r'^2 . \frac{r' - r_0}{r'}$ which, in this case, should equal the resistance of the vessel.

Useful work per second = $2\pi n T r_0$ = resistance × speed of ship.

Total work = $2\pi n r' T$ = resistance or thrust × speed of paddle.

Efficiency = $\frac{r_0}{r'}$ = 1 — slip.

In applying these formulæ to the *City of Fall River*, we have taken the same data as that used in calculating the probable speed for the two complete trips of May 3 and 4, and May 9 and 10. The mean centre of pressure was found from the following formula deduced mathematically by Van Buren.*

$$x = R_2 \frac{3(1-p^4) - 8(1-p^3)\, m \cos.\varphi + 6(1-p^2)\, m^2 \cos.^2\varphi}{4(1-p^3) - 12(1-p^2)\, m \cos.\varphi + 12(1-p)\, m^2 \cos.^2\varphi}$$

in which R_2 and R_1 = outer and inner radii to bucket, φ = angle of bucket with vertical, $p = \frac{R_1}{R_2}$; m = ratio of velocity of vessel to velocity of outer circumference of wheel. cos. $\varphi = 1$, $R_2 = 12{\cdot}75'$, $R_1 = 9{\cdot}416,'$ $p = {\cdot}7385$ $m = {\cdot}7$. Substituting these gives for x or the distance from centre of wheel to centre of pressure, $11{\cdot}22'$. Hence $x = r' = 11{\cdot}22'$.

	First Trip.	Second Trip.
n = ...	·4286	·427
$\frac{r' - r_0}{r'}$ = ...	·192	·204
Resistance = ...	23721	24836
Thrust = ...	23589	24772
Difference = ...	132	64
Efficiency = ...	80·8 per cent.	79·6 per cent.

	First Trip.	Second Trip.
$2\pi Tnr'$ = ...	709,740 ft. lbs. per second.	745,690 ft. lbs. per sec.

which are the energies in foot-pounds per second expended in driving

* Journal of Franklin Institute, Vol. 49, 1865.

paddles, exclusive of friction. Dividing by 550 we have for the corresponding horse-powers exerted effectively in driving paddles:

	First Trip.	Second Trip.
Horse-powers.....	1290	1355
Indicated horse-power,.....	1595	1619
Horse-power expended in overcoming friction,	305	264

The mean efficiency of the engine and mechanism of the wheel is given by the quotient of mean effective horse-power, divided by mean indicated horse-power, which is $\frac{1322{\cdot}5}{1607} = 82{\cdot}3$ per cent.

The resultant efficiency of engines and paddles is the product of the mean efficiency of each, or 80·2 per cent. × 82·3 per cent. = 66 per cent.

The resistance of the vessel as given above was computed from Rankine's formula, using a coefficient diminished in the ratio of the coefficients of propulsion, or 23,500 to 20,000; the latter of which was determined by Rankine from experiments on iron ships, and the former by Messrs. Elliott and Lieb from experiments on copper-bottomed vessels of similar form to the one under consideration.

This reduced formula is

$$R = \frac{\text{Augmented surface} \times \text{square of speed in knots.}}{117{\cdot}5}$$

In Rankine's formula, given in his "Ship-building," the constant as determined for iron ships is 100.

The differences above between the resistances and thrusts, being 132 in the first case and 64 in the second, must be owing somewhat to errors of assumption, such as neglecting the following current, and also to approximate computations. In the paddle efficiency here given, no loss is considered but that due to slip.

The additional losses are those due to the small amount of oblique action and to friction. The first, though undoubtedly slight, must still be more in a wheel of 4 feet 9 inches dip, as in the present case, than in one having the buckets simply immersed; but owing to the complexity of the action in a wheel of this sort, due to dip and varying angles, as well as varying centre of equal radial wheel, it is impossible to determine with any degree of certainty the losses due to this cause. Friction is greater here than with a radial wheel,

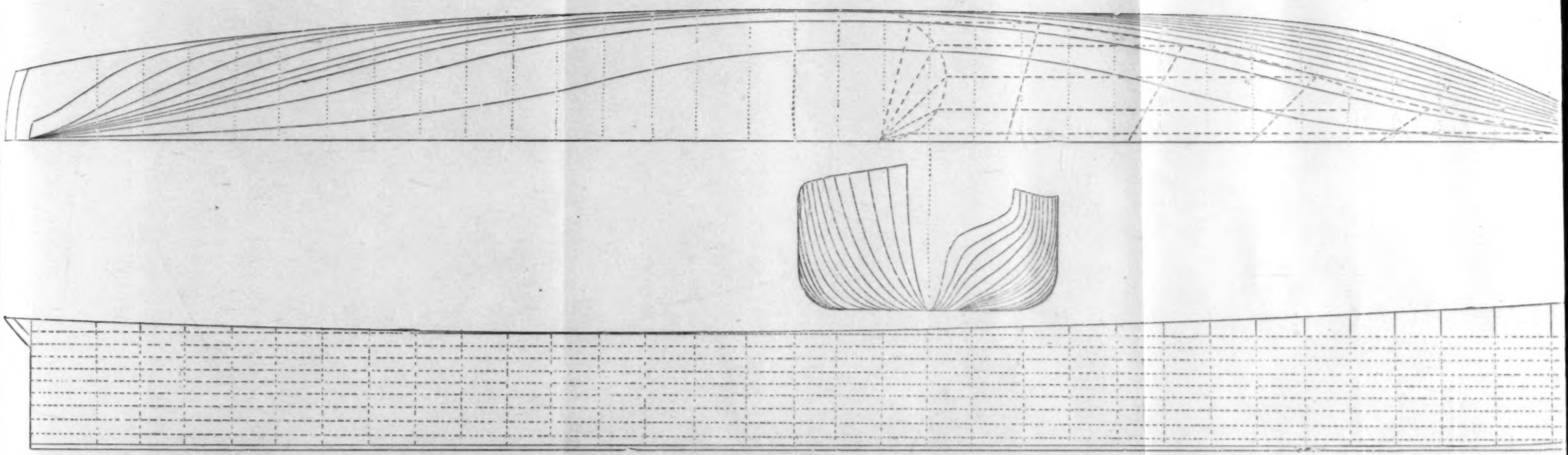

FIG. 1. LINES OF STEAMER "CITY OF FALL RIVER."

paddles, exclusive of friction. Dividing by 550 we have for the corresponding horse-powers exerted effectively in driving paddles:

	First Trip.	Second Trip.
Horse-powers	1290	1355
Indicated horse-power,	1595	1619
Horse-power expended in overcoming friction,	305	264

The mean efficiency of the engine and mechanism of the wheel is given by the quotient of mean effective horse-power, divided by mean indicated horse-power, which is $\frac{1322{\cdot}5}{1607} = 82{\cdot}3$ per cent.

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This reduced formula is

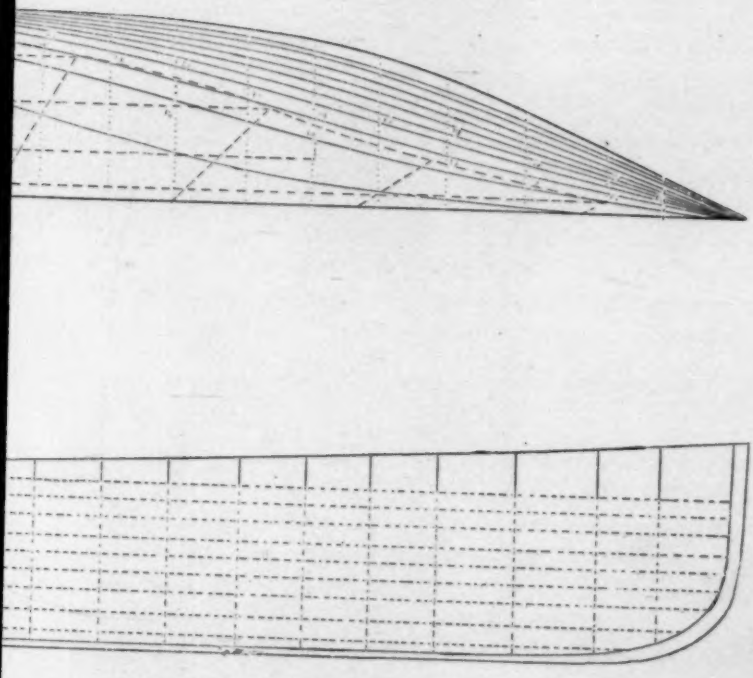
$$R = \frac{\text{Augmented surface} \times \text{square of speed in knots.}}{117{\cdot}5}$$

In Rankine's formula, given in his "Ship-building," the constant as determined for iron ships is 100.

The differences above between the resistances and thrusts, being 132 in the first case and 64 in the second, must be owing somewhat to errors of assumption, such as neglecting the following current, and also to approximate computations. In the paddle efficiency here given, no loss is considered but that due to slip.

The additional losses are those due to the small amount of oblique action and to friction. The first, though undoubtedly slight, must still be more in a wheel of 4 feet 9 inches dip, as in the present case, than in one having the buckets simply immersed; but owing to the complexity of the action in a wheel of this sort, due to dip and varying angles, as well as varying centre of equal radial wheel, it is impossible to determine with any degree of certainty the losses due to this cause. Friction is greater here than with a radial wheel,

[*Sague and Adger.*]



paddles, exclusive of friction. Dividing by 550 we have for the corresponding horse-powers exerted effectively in driving paddles:

	First Trip.	Second Trip.

to this cause. Friction is greater here than with a radial wheel,

embracing both fluid and journal friction, each of which is indeterminate by analysis.

DESCRIPTION OF ENGINE.

The engine of the *City of Fall River* was built by Messrs. W. & A. Fletcher, of New York, from the designs of their superintendent, Mr. Stevenson Taylor. It is a vertical "beam engine," compounded and fitted with a surface condenser, and capable of indicating 2,000 horse-power. It is similar in general appearance to the ordinary American beam engine, but has two cylinders,—a high and a low pressure,—both connected to the forward end of the beam.

The piston of the low pressure cylinder is connected to the end of the beam by a pair of links journaled on a cross-head sliding in vertical guides, which are bolted to the cylinder head and supported by stays from the "gallows frame." The high-pressure cylinder is placed just abaft the low-pressure, and connected to the beam in the same manner, one-third the distance from the forward end to the centre. The connecting-rod, placed at the after extremity of the beam, actuates the paddle-shaft, while the air-pump plunger is driven by a pair of links, journaled on the same side of the beam at an intermediate point. There is a single acting feed-pump for each of the two boilers, the plungers of which are driven directly from the air-pump cross-head. The gallows-frame is of wood and of the ordinary design. It is composed of struts diverging from the beam centre pillow-blocks and strongly framed together by longitudinal pieces and knees, and resting upon horizontal beams beneath the engine bed-plate. The paddle-shaft pillow-blocks are placed between two of the main struts near their lower ends, the shaft itself revolving beneath the main deck.

The steam pipes from the boilers unite near the high-pressure steam chest, which takes steam at the lower end and distributes it through side pipes to the upper valves. The receiver is simply an enlarged steam pipe taking the exhaust from the high-pressure cylinder and leading it to the bottom of the low-pressure chest, where it is carried through side pipes as before.

The steam pipes are so arranged that the steam can be led directly into the receiver by introducing a pipe which lies at hand. The high-pressure cylinder can then be disconnected by closing its throttle and stopping up its exhaust pipe. The live steam from the boiler is thus carried directly into the low-pressure cylinder, and by disconnecting

the high-pressure piston rod the engine is converted completely into the simple type of an ordinary American beam engine. The steam is distributed by double poppet valves and the Stevens gear; the steam and exhaust valves being actuated by independent eccentrics through a system of cams or "wipers" placed upon horizontal rock-shafts, and "toes" fastened upon the valve rods. The cut-off is fixed and the valves are adjusted, as usual with this form of gear, to close at about half stroke in each engine. The condenser is placed beneath the cylinders, and is rectangular in shape. The condensing water is forced through tinned copper tubes, around which the exhaust steam flows. A centrifugal pump of a capacity of about 5,000 gallons per minute is used as a circulator, and is driven by a small vertical engine taking steam from the main boilers.

The steam chests and side pipes all have a coating, half an inch in thickness of mineral wool, outside of which is wood-lagging, and the whole covered with a thickness of Russian iron. The cylinders are covered partly with a layer of mineral wool and partly with felting, outside of which is a layer of wood-lagging put on in the usual manner. The steam pipes are all felted. Neither cylinder is steam-jacketed. The principal dimensions of the engines are as follows:

Distance of top of engine frame above engine keelsons	39	feet	10	inches.
Length of beam between centres	26	"		
Depth of beam outside to outside of strap	12	"	6	"
Length of connecting rod	28	"	9	"
Diameter at centre*			12½	"
Diameter at ends			8	"
Diameter of paddle-shaft in main journals			16½	"
Diameter of crank pin			9½	"
Length of crank pin journal			12	"
Length of each beam centre journal			17	"
Diameter of beam centre journal			11	"
Diameter of main steam pipes			14	"
Diameter of air-pump			37	"
Stroke of air-pump	4	"	9	"
Diameter of feed-pumps			5⅜	"
Stroke of feed-pumps			57	"
Length of L. P. links from centre to centre	9	"		
Length of H. P. links from centre to centre	15	"	2	"

* Made heavy, so that rod with air-pump will balance extra weight of high pressure piston, cross-head and links.

Volume of receiver	89·13 cubic feet.
Number of condenser tubes	2,431
Length of each	9 feet.
Diameter of each	¾ inches.
Amount of condensing surface	4,057 square feet.
High-pressure cylinder, diameter	44 inches.
High-pressure cylinder, stroke	8 feet.
Net area of each steam port in percentage of piston area	10· 7 per cent.
Same for each exhaust port	11·02 "
Total volume in clearance and steam passage at top. Same for bottom, average	3·845 cubic feet.
Average clearance at each end in percentage of stroke volume	4·6 per cent.
Total length in clearance	2½ inches.
Diameter of piston rod	6½ "
Low pressure cylinder, diameter	68 "
Low pressure cylinder, stroke	12 feet.
Net area of each steam port in percentage of piston area	7·1 per cent.
Same for each exhaust port	7·3 "
Total volume in clearance and steam passage at top. Same for bottom, average	9·18 cubic feet.
Average clearance at each end in percentage of stroke volume	3·05 per cent.
Total length in clearance	2 inches.
Diameter of piston rod	7½ inches.

BOILERS.

There are two return tubular boilers, one set forward and the other abaft the engine, directly over the keel. They are of the Redfield tubular pattern, each having two shells made of half-inch Otis steel plates, double riveted on longitudinal seams, and calculated to carry a working pressure of one hundred pounds per square inch. Each boiler is provided with a superheater surrounding the uptake, which, however, is not designed to give any considerable degree of superheating, but merely to dry the steam. The steam pipes are carried from this chamber. Each boiler has two separate furnaces, and four fire-doors. Natural draft alone is used.

The principal figures are as follows:

Total height to top of superheater	24½ feet.
Length of each boiler	15 "
Width of each boiler	17½ "
Diameter of each shell	7½ "

Number of tubes in each shell	110
Length of each tube	12 "
Diameter of each tube	3½ inches.
Diameter of uptake	56 "
Diameter of superheater	96 "
Height of superheater	12 feet.
Area of grate surface in each boiler	115 sq. feet.
Area of water heating surface in each boiler.	3,845 "
Area of steam heating surface in each boiler.	205 "
Ratio of water heating to grate surface..	29
Ratio of total heating to grate surface..	30·87
Weight of each boiler	51½ tons (net)
Weight of water in each boiler..	27 " "
At 12 inches above tubes	

MANNER OF MAKING TESTS.

The experiments upon the Steamer *City of Fall River*, for the purpose of ascertaining the economy of her engines and boilers were made during the regular trips of the vessel between the cities of New York and Fall River, and in each case were performed on both the outward and return passages, the time occupied in each, being from ten to twelve hours, the runs being make during the night. The times chosen for making the trials were such as simply suited our own convenience and the conditions were all those of ordinary running, not the slightest change or adjustment having been made by either the engineers or the builders to secure high results, and those obtained are reliable indications of the daily performance. All the observations and measurements were made that are necessary to a satisfactory test of both the engines and boilers, and all were made by persons accustomed to the duty and acquainted with the objects in view and interested in the thorough performance of the work.

The principal measurements were checked as far as possible by having them made independently, and the agreement of the results obtained upon successive trips proves conclusively the accuracy of the work. The water measurements, being those upon which the success of the test most largely depended, need a somewhat complete description. Owing to the great expense necessary to fit up tanks to measure the water in the ordinary manner, as well as the difficulties arising from handling the great quantities used while the vessel is in free route, it was decided to use meters, and the Worthington piston meter was adopted as the one most certain of giving accurate results under the

prescribed conditions. Two three-inch meters each capable of measuring 18 cubic feet of water per minute, were furnished for the test by the Worthington Hydraulic Works of Brooklyn, who also furnished the plans for the meter connections, and suggested the manner of testing them. A meter *A* was placed as near as possible to each boiler,

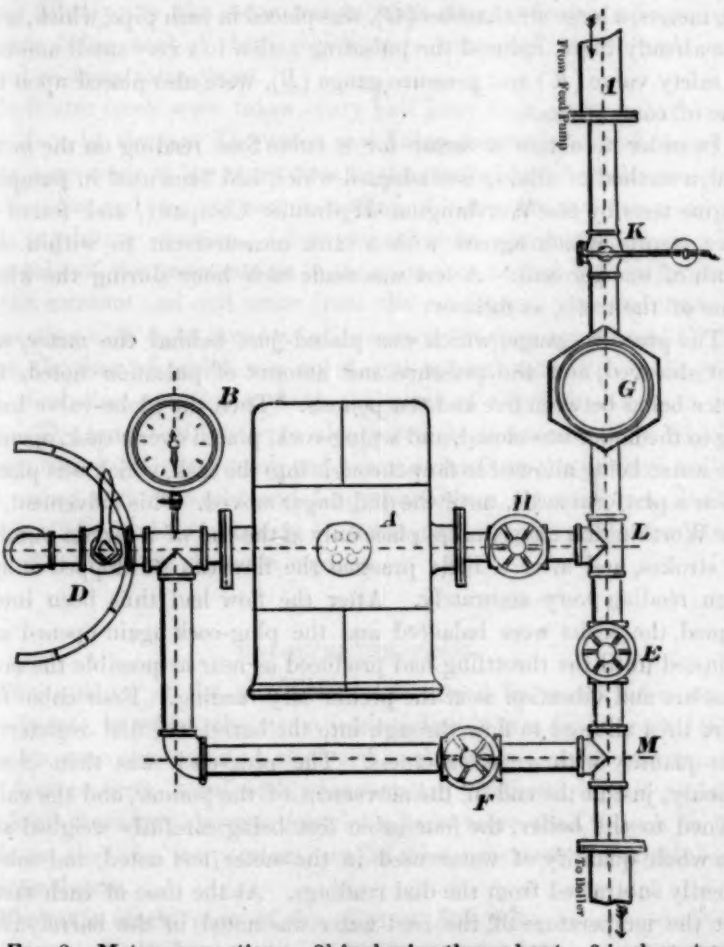


FIG. 2.—Meter connections. 2½ inch pipe throughout. 3 inch meter.

and introduced by taking out a piece of the feed-pipe, (*I*). On the line of this joint was placed a bye-pass, (*G E*) from which connections were made by "*Ts*" (*L M*), to pipes leading to the meter, (*A*) which

rested upon a platform as near as possible to the main feed-pipes, (*I*). A globe valve (*H & F*) was placed in each pipe so that the water could be shut off from the meter when the latter was not needed, and allowed to go direct to the boiler. The feed-pumps being single acting and connected to the beam tend to cause a violent shock at each stroke of the engine, and for the purpose of lessening this and to avoid injury to the meters, a large air chamber (*G*), was placed in each pipe, which, with one already there, reduced the pulsating action to a very small amount. A safety valve (*K*) and pressure gauge (*B*), were also placed upon the line of connections.

In order to obtain a factor for a cubic foot reading on the meter dial, a method of testing was adopted which had been used in pumping engine tests by the Worthington Hydraulic Company, and found to give results which agreed with a tank measurement to within one-tenth of one per cent. A test was made each hour during the whole time of the trials, as follows:

The pressure-gauge, which was placed just behind the meter, was first observed, and the pressure and amount of pulsation noted, the latter being between five and ten pounds. Then the globe-valve leading to the boiler was closed, and a plug-cock, placed over a cask, opened, the water being allowed to flow through into the cask, which was placed upon a platform scale, until the dial finger moved. This movement, in the Worthington meter, takes place only at the end of a certain number of strokes, and after a little practice the flow can be stopped at any even reading very accurately. After the flow had thus been interrupted, the scales were balanced and the plug-cock again opened and adjusted until the throttling had produced as near as possible the same pressure and vibration as at the preliminary reading. Four cubic feet were then allowed to flow through into the barrel, the dial registering this quantity with great exactness. The plug-cock was then closed quickly, just at the end of the movement of the pointer, and the valve opened to the boiler, the four cubic feet being carefully weighed and the whole quantity of water used in the meter test noted, and subsequently subtracted from the dial readings. At the time of each meter test the temperature of the feed-water was noted in the barrel, after which it was emptied into the bilge.

The results of the ten or twelve meter tests thus secured each night under the exact conditions of use, do not differ in any important degree from each other, and the average being taken, permit the calculation

of the water consumption with as great a degree of accuracy as could be reached by any tank measurement. The dial readings and water-levels at each boiler were noted simultaneously at hourly intervals, allowing the calculation of the engine economy to be made between any required points.

All the coal was weighed in boxes upon platform scales, the boxes being filled up to the same weight each time, and two independent records being kept of them, which were compared at intervals and found to agree throughout.

Indicator cards were taken every half hour from each end of both cylinders, by the best Thompson and Tabor instruments, and observations were made at the same time in the engine room, of the pressure in the steam and receiver guages, reading of barometer and thermometer and revolution counter. Observations were also made, at regular intervals, of the temperatures in the chimneys, and of the temperature of the entrance and exit water from the condenser. At the moment of passing each light-house a bell was rung in the engine room by the pilot, the time of which was noted and entered with the reading of the revolution counter, opposite the name of the light-house on the log. The wind and tide were also noted at intervals. The Sickles Steam Steering Gear is used, and takes steam from the forward boiler, but owing to the straight and long courses run, the work required of it was slight, and the quantity of steam used inappreciable compared with that taken by the main engines.

CALORIMETER TESTS.

The quality of the steam was determined by means of a steam calorimeter, in which the steam was condensed in a copper coil. The weights were obtained on a steelyard graduated to quarter ounces, and the temperatures noted on a thermometer graduated to half degrees. Each of these half degrees occupies a little more than $\frac{1}{8}$ inch on the scale, so that the temperature can be read accurately to within one quarter degree.

The main steam pipe of the *City of Fall River* was tapped just in front of the high pressure steam chest and a half-inch pipe, upon which a long thread had been cut was inserted, until it extended several inches up into the steam pipe, and drew its supply from near its centre. From this half-inch pipe a steam hose conveyed the steam to the calori-

meter, and on this pipe were a steam gauge and a steam thermometer, on which the pressure and the temperature of the steam could be observed. All the observations were made by men accustomed to the use of this calorimeter and were as accurate as could be obtained.

Each test was entered upon a log previously prepared for the purpose, having columns for time, initial and final weights of the water in the calorimeter, initial and final temperatures of the water in the calorimeter, steam gauge pressure and the temperature from the steam thermometer.

In calculating the results, an allowance has been made for the absorption of heat by the calorimeter itself; this amount having been previously determined accurately for the range over which the calorimeter was used. Also, as the water used was for convenience seawater, an allowance has been made for the specific heat of the salt contained therein. $\frac{1}{32}$ was taken as the saltness of the water and ·555 as the specific heat of the salt in the fluid condition. This allowance was found to make 70 pounds of seawater equivalent to 68·786 pounds of fresh water, and this figure was used in the calculations.

On the night of May 9th, nine tests were made, giving an average of 1.65 per cent. priming. The range of the nine figures obtained was from + 5·4 per cent. to — 1·49 per cent.; two of the nine being negative, or showing a slight degree of superheating.

On the night of May 10th, seven tests gave an average of 0·67 per cent. priming. The range was from + 3·67 to — 4·76. Three of the seven showed superheating.

BOILER TESTS.

In making a boiler test to ascertain its evaporative power, it is necessary to start the test with a certain level of water in the boiler and a certain pressure of steam registered upon the gauge. At the close of the test the water should stand at the original level and the steam pressure falling, *i. e.*, the fire pretty well burnt out. Between the beginning and end of the test every pound of coal and ash should be carefully weighed, and all the water supplied to the boiler accurately measured. It is customary to raise the steam up to the gauge pressure at which the test is to be made, with a wood fire; to then draw this fire, and make a new one as quickly as possible with weighed fuel, and begin the test from the lighting of this second fire. Towards

the end of the test the fire is allowed to cool down, and the water is pumped up to the original level, or the difference of level is noted, and the remains of the fire are drawn out and weighed as ash.

It should be kept prominently before the mind that the tests of the *City of Fall River* were made during the regular trips of the boat without any special previous preparation, and, therefore, the impracticability of fulfilling the above named conditions as to starting rendered an exact boiler test impossible.

An approximate figure, however, and one very closely approximate can be obtained upon the following basis: Upon the vessels reaching port each morning, the fires are cleaned and banked, and to this bank coal is added about noon. About two hours before starting in the afternoon the banks are pulled down and spread, and coal is thrown upon the fires. The steam made is allowed to blow off through the escape valves until the hour for leaving approaches. The valves are then closed and the pressure allowed to run up to about 65 pounds. By ascertaining the level of water in the boilers at the time of spreading the fires, and also its temperature, we can get the number of heat units required to raise this amount of water up to the temperature corresponding to the boiler pressure at the start, and we can find the number of pounds of water which this number of heat units could have evaporated. Thus we can account for that part of the coal used in raising the temperature of the water in the boiler. But the whole boiler, weighing in this case 51·5 tons, is heated up and the rise of temperature varies considerably for the different parts. What this rise is, cannot be exactly stated, but it is deemed fair to assume that the whole boiler is heated from the temperature of the water in it at the time of "pulling the banks" to the temperature corresponding to the steam pressure when the engine starts. The whole boiler is therefore treated as a mass of iron and by multiplying this weight by the specific heat of iron and by the rise of temperature, we can get the number of heat units absorbed in heating up the boiler. Another source of perplexity is the bank, consisting in each case of 2,000 or 3,000 pounds of coal, consumed partly, but how much it is impossible to state. The assumption here made was that the banks balanced and that the coal thrown on at noon was merely equivalent to the consumption of the bank during the day, and on this assumption every pound of coal put on the fires, from the time of "pulling the banks"

until the fires is banked the next morning, in port, is charged to the boilers. This assumption is at least safe as the error in it is certainly against the boiler. Upon these assumptions the following table is made out. The coal for the three nights was carefully weighed and the temperature of the water at the time of "pulling the banks" and the various water levels on each occasion were noted and entered upon the logs. The exact widths of the boilers at various levels were obtained from the drawings in the possession of the builders, and the different weights of water at the different levels were very carefully calculated. The specific heat of iron was taken as ·1138. The weight of the boiler multiplied by this figure and by the rise of temperature gives the number of thermal units absorbed, and this number divided by the difference between the total number of thermal units contained in the steam at the boiler pressure and the temperature of the feed, gives the number of pounds of water, which the heat expended in raising the temperature of the boiler could have evaporated. This amount is added to the total number of pounds evaporated by the boiler. For example, on the night of May 10th, the temperature of the feed was 97·16° Fahr.; the total number of heat units of one pound of steam at the boiler pressure was 1209·56; the difference between the two numbers is 1112·4. We then have 103,000 pounds, the weight of the boiler, multiplied by ·1138, the specific heat of iron, and by 130°, the range over which the temperature was raised, equal to 1,523,782. This number divided by 1112·4 gives 1,369 pounds of water, as the number which the heat absorbed in heating up the boiler might have evaporated, and this amount is added to the total number of pounds with which the boiler is credited.

The same process is pursued in all the tests. The difference, seen below in the percentage of ash, is due no doubt to difference in firing forward and aft.

RESULTS OF BOILER TRIAL.

Position of Boiler.	For'd.	Aft.	For'd.	Aft.	For'd.	Aft.
Date of test.	May 4	May 4	May 9	May 9	May 10	May 10
Length of test (hours)	13	13	12·5	12·5	12·5	12·5
Total coal burned (lbs.)	18922	21314	18294	22083	18186	21650
Total refuse, ash, etc. (lbs.)	3699	3427	3518	3206	3449	3503
Total combustible (lbs.)	15223	17887	14776	18877	14737	18147
Percentage of refuse, ash, etc	19·55	16·08	19·23	14·52	18·97	16·18
Total water evaporated (lbs.)	154106	183785	151057	182919	144391	176576
Average Steam Guage Pressure	68·5	68·5	70	70	70	70
Average height of barometer	30·70	30·70	30·70	30·70	30·5	30·5
Average temperature of feed water (Fahr.)	102·03	101°	97·1°	97°	97°	97·3°
Average temperature of atmosphere (Fhr.)	74°·	74·°	78°	78°	77°	77°
Average temperature of chimney gases (Fahr.)	485°	485°	485°	495°	495°	416°
Number of pounds of coal per hour per sq. ft. of grate	12·657	14·257	12·726	15·292	12·646	15·069
Number of pounds of water evaporated from the temperature of feed per lb. of coal	8·14	8·62	8·257	8·24	7·939	8·156
Number of pounds of water evaporated from the temperature of feed per lb. of combustible	10·117	10·27	10·22	9·689	9·797	9·732
Number of pounds of water evaporated from and at 212° F. per lb. of combustible	11·59	11·77	11·75	11·08	11·206	11·102

(To be concluded.)

ATMOSPHERIC CHANGES AT NICE.—Since the appearance of the brilliant sunsets, Messrs. Thollon and Perrotin have noticed that the sky at Nice seems to have lost much of its ordinary transparency. They have been accustomed, on every fair day, to examine the sky in the neighborhood of the sun, placing themselves near the border of the shadow projected by one of the observatory buildings. When thus sheltered from the direct rays of the sun, they have noticed in former years that the blue of the sky continued to the very borders of the solar disk. If they were so placed that the disk was almost a tangent to the border of the screen, but still invisible, no increase in the brilliancy of illumination indicated the place where the point of tangency would be found. This is now no longer the case. Since the month of November, even upon the brightest days, the sun appears constantly surrounded by a circular fringe of dazzling white light, slightly tinged with red at its outer edge, and with blue on the inner edge. There is a sort of ill-defined coronna, with an apparent radius of about fifteen degrees. It would be interesting to know whether this fact is general and whether it can be considered as connected with the volcanic dust or other causes of the late brilliant twilights.—*Chron. Industr.*, April 6, 1884.

TESTS BY HYDROSTATIC PRESSURE.

By S. Lloyd Wiegand, M. E.

[Read at the Stated Meeting, Wednesday, June 18, 1884.]

In the course of some experiments, made for testing the strength of vessels to resist internal pressure, some important facts appeared, which although not directly relevant to the immediate purpose of the inquiry, appeared interesting and important to several acquaintances engaged practically in similar operations, and upon an interchange of experiences and opinions with them, the writer found that these facts were either not generally known, or else their importance had been frequently overlooked where they should have been considered and attentively regarded.

The matters referred to are the performances of the apparatus used for testing by hydraulic or hydrostatic pressure, and the inaccuracies of pressure recording gauges.

In the matter of applying hydrostatic pressure, the momentum of the fluid as forced into the vessel plays an important part, and sometimes, if not frequently, by concussion, causes ruptures or leaks in vessels at pressures far below those that they have resisted under slow and steady application of hydraulic force.

When force pumps of large displacement are used, the shock of fluid-column delivered at each stroke is very appreciable in producing a pulsation or intermittent bulging or dilation of flat surfaces, and leakage and rupture occurs at a moment coincident with or instantly following the sudden injection of the fluid, and the indices of the pressure gauges jump to an indication of pressure far beyond that which they settle at. This is specially noticeable in what is known as maximum recording gauges, the rising and returning motions of the index to which motion from the pressure is first imparted being often so sudden as to escape observation, and the recording index may be seen standing considerably beyond the point to which the eye can follow the moving index.

When a pump with a smaller plunger is used, the pulsation of the flat parts of the vessel is much less appreciable, and oscillations of the gauge indices are proportionally reduced, whilst at the same time the pressures reached before leakage and rupture are greatly increased.

These differences in performance under different proportions of apparatus are so well understood by the makers of machines for testing the tensile strength and properties of metals by weighing beams combined with a hydraulic jack or press, that they employ a series of very small reciprocating force pumps so worked by cams or cranks from a revolving shaft as to effect an almost uniform delivery of fluid to the ram of the jack, and their experience shows results not procurable by intermittently or concussively acting pumps; pressure produced by the use of an injector produces like results.

The steady or more uniform application of pressure has sometimes been accomplished by charging an accumulator, similar to those used for hydraulic elevators and cranes, with fluid under a pressure equal to the intended test, and then cautiously admitting the fluid to the vessel under test. The cost and want of portability in this apparatus, as well as the risk of accident from sudden liberation of pressure by rupture, form an objection to this mode of working, and limits its application to situations where frequent tests are to be made of small vessels.

In such apparatus, a valve operating so as to automatically shut the flow from the accumulator as quickly as any rapid flow or fall of pressure occurs in the delivery pipe, is a useful adjunct.

Air vessels have been proposed and sometimes used in conjunction with pumps for this service, but the tendency to throw as projectiles, the fragments of the vessel after bursting it, renders such methods unsafe—it is, however, satisfactorily used in conjunction with strong surrounding guards or cages for the testing of glass bottles and fountains, made for charging, storing, and transporting aerated waters.

The inaccuracy of gauges for measuring high pressures is also a matter of interest in hydrostatic testing operations—none of those which depend on an expansible vessel or diaphragm, and a system of motion multiplying levers or sectors and pinions conveying motion to the index, are without the objection of friction of working parts, and under different conditions of lubrication are not only liable, but certain to vary.

The inaccuracy of pressure gauges of this type is so slight as to be unimportant in gauges for such pressures as those under which steam is ordinarily used, compared with those required for high pressures, such as are employed in testing for ultimate strength of vessels, and for the liquefaction of gases, which, by the by, is now practiced on a

commercial scale as an industry of considerable importance, when the inaccuracy is quite noticeable, and sometimes embarrassing in practice; the use of more than one gauge at the same time, arranged so as to be in view at once, serves as a measurably good precaution.

In the course of an experiment made before the members of this Institute, the two recording gauges were found to keep within twenty-five or thirty pounds of each other, and in testing them before and after the experiments with other gauges up to the highest pressure indicated in the experiment, they were found not to have set or changed in the elasticity of their springs.

The experimental test made in the presence of the members of the Institute is believed to have been adequate for the purpose for which it was intended, namely: to show that such structures as have been used, and are now in use, are not so unsafe as to call for any public alarm on the subject; but at the same time, that it was desirable to have more exact information than was accessible in publications on the subject, and the propriety of further inquiry by a series of experiments in such direction and an investigation, which investigation is now in progress.

In the experiment referred to, some other interesting matters appeared among others, those to which attention is directed in this paper.

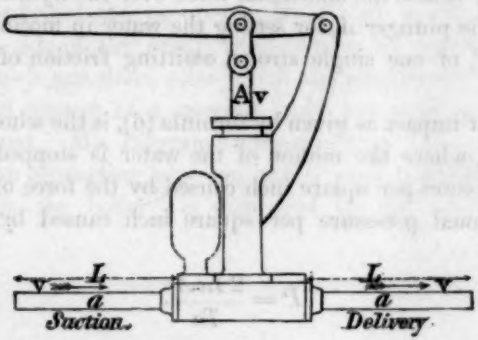
DISCUSSION.

Mr. Hugo Bilgram:—Considering that the transmission of strain in a fluid takes place with the velocity of sound in that fluid, and that therefore such transmission is practically instantaneous, the momentum of the water in the connecting pipe can hardly even temporarily increase the pressure in the boiler much beyond that due to the quantity of water forced into the same, and owing to the elasticity of the walls of the boiler the pressure is practically proportionate to the amount of water forced into it after it had been filled. The momentary pressure caused by the momentum of the water in the connecting pipe at the conclusion of any stroke of the pump can certainly not exceed the permanent pressure due to any of the following strokes.

Mr. J. W. Nystrom:—The momentum and force of impact of water moving in pipes are well known to hydraulic engineers, as can be seen in hydraulic machinery in which precautions for these forces

are properly made, and the science of which may be represented as follows:

The accompanying illustration represents a pump of plunger A, suction and delivery pipes, a, a.



A = cross area of plunger in square feet.
a = cross area of suction or delivery pipe.
v = velocity of plunger in feet per second.
V = velocity of water in the pipes per second.
L = length of pipe in feet.
W = weight of water in pipe in pounds.
g = 32·17 the acceleratrix of gravity.
F = force of impact in pounds.
T = time in seconds in which the impact acts.

Velocity of water in pipe $V = \frac{Av}{a}$. (1)

Momentum of motion $\frac{WV}{g} = FT$, momentum of time. (2)

Force of impact $F = \frac{WV}{gT}$. (3)

Insert formula (1) for V in formula (3), and we have

$$F = \frac{WAv}{gTa}. \quad (4)$$

Weight of water in pipe $W = 62{\cdot}4\ aL$. (5)

Insert formula (5) for W in formula (4), and we have

$$\text{Force of impact } F = \frac{62{\cdot}4\ aLAv}{gTa} = \frac{62{\cdot}4\ LAv}{gT} = \frac{2\,LvA}{T}. \qquad (6)$$

The acceleratrix g divided into the weight per cubic foot of water 62·4 pounds, is nearly 2.

The force F is also the additional force over the hydrostatic pressure required on the plunger A, for setting the water in motion in the pipe, in the time T, of one single stroke, omitting friction of the water in the pipe.

The force of impact as given by formula (6), is the whole force acting on the area a, where the motion of the water is stopped, and not the additional pressure per square inch caused by the force of impact.

P = additional presssure per square inch caused by the force of impact.

$$P = \frac{2\,LvA}{Ta}. \qquad (7)$$

In this formula (7) the areas A and a can be expressed in square inches, but L must be expressed in feet. It is this formula which expresses the difficulty with momentum and concussion spoken of in Mr. Wiegand's paper. We find that this difficulty is proportionate to the length L, of the pipe, area A and velocity v of the pump plunger, and inversely as the time of impact and area a of the delivery pipe.

In the hydraulic boiler test made by Mr. Wiegand before the February meeting of the Institute, the delivery pipes were, as near as I can remember, about three-eighths of an inch inside diameter, and that of the plunger one inch, which makes the area of the plunger about seven times that of the pipe. The delivery pipe was entirely too small, and should have been at least one inch inside diameter, but $1\frac{1}{2}$ inch would be better.

The data in the experiment referred to, were about $L = 6$ feet, $v = 0{\cdot}5$, $A : a = 7$. $T = 0{\cdot}25$. Then the impact pressure would be as follows:

$$P = 2 \times 4 \times 6 \times 0{\cdot}5 \times 7 = 168 \text{ pounds per square inch.}$$

Now suppose the delivery pipe to be $1\frac{1}{2}$ inches diameter, and the other data remain as they were, then the impact pressure would be only

$$P = 2 \times 4 \times 6 \times 0{\cdot}5 \times 0{\cdot}444 = 10{\cdot}6 \text{ pounds per square inch.}$$

The elasticity of the vessel in which the water is forced, and the air in the water diminishes considerably the force of impact, but the

formulas, however, shows that the delivery pipe should be large in diameter for reducing the force of impact.

A steam pump for a marine railway at Portero, near San Francisco, California, had a suction pipe of about 400 feet long, and the force of impact of that column of water was so great that it finally burst the pipe. I then advised the proprietor, Mr. North, to put an air vessel on the suction side of the pump, as shown by the dotted line on the illustration, which was done, after which the plunger worked well.

The force of impact of a moving body has nothing to do with velocity of sound. Mr. Bilgram's statement that "the momentum of the water in the connecting pipe can hardly even temporarily increase the pressure in the boiler" is disproved by the operation of the hrdraulic ram.

VELOCITY OF APPROACH IN WEIR COMPUTATIONS.

TO FACILITATE THE COMPUTATION OF WEIR DISCHARGES, CORRECTED FOR VELOCITY OF APPROACH, BY A METHOD BASED ON THE FORMULÆ AND PRESCRIPTIONS OF THE LOWELL HYDRAULIC EXPERIMENTS.

By A. W. Hunking and Frank S. Hart, Lowell, Mass.

The following adaptation of the Francis formula for correcting weir discharges for velocity of approach was suggested by personal observation of the great amount of time consumed in the necessary weir computations pertaining to a general business of water measuring.

In an extended series of turbine tests like those published in Lowell Hydraulic Experiments, and in Journal Franklin Institute for April, 1875, involving the weir measurement of large quantities of water, with great depth on the weir, it is believed that the proposed method presents great advantages over the one commonly employed, both in brevity and accuracy.

The formula referred to, viz.:

$$Q = (L - 0{\cdot}1\, nH)\,[3{\cdot}33\,(H + h)^{\frac{3}{2}} - 3{\cdot}33\, h^{\frac{3}{2}}] \qquad (1)$$

may be found in Lowell Hydraulic Experiments, p. 252 (Ed. 1883).

The notation adopted is as follows:

Q represents the quantity of water discharged in cubic feet per second.
L " length of the weir, in feet.
H " height of water above crest of weir as observed at section S, in feet.
S " area of section of approach, in square feet.
v " velocity of approach, in feet per second.
h " $\frac{v^2}{2g}$ or head due velocity of approach, in feet.
n " number of end contractions.

To correct the discharge over the weir for the velocity of approach, by the above formula, the method commonly employed has been to make successive approximations to the value of Q; beginning with the formula [which is the same as equation (1), except that h is omitted, having been assumed as zero]

$$Q = 3{\cdot}33\,(L - 0{\cdot}1\,nH)\,H^{\frac{3}{2}} \qquad (2)$$

and deducing from this value of Q, and the assumed section of approach of the current above the weir, an approximate value of h, to be used in equation (1), which, being solved, gives an increased value of Q, and this in turn may give a slightly increased value of h to use in a second solution of equation (1), and so continuing until the desired accuracy in the value of Q is obtained.

It is proposed to show in this paper that, to correct for the velocity of approach, a coefficient, K, depending upon the value of $\frac{h}{H}$ (where H is the observed depth on the weir, and h is the head due the *true* velocity), may be used, and that we may write

$$Q = 3{\cdot}33\,(L - 0{\cdot}1\,nH)\,H^{\frac{3}{2}}\,K, \qquad (3)$$

in place of

$$Q = 3{\cdot}33\,(L - 0{\cdot}1\,nH)\,[(H + h)^{\frac{3}{2}} - h^{\frac{3}{2}}]. \qquad (1)$$

When K can be taken from a table, or read directly from a diagram, it is obvious that the solution of equation (3) is far less laborious than the method first mentioned.

By reference to equations (1) and (3) it will be seen that $H^{\frac{3}{2}}\,K$ is substituted for $[(H + h)^{\frac{3}{2}} - h^{\frac{3}{2}}]$, making

$$K = \left(\frac{H + h}{H}\right)^{\frac{3}{2}} - \left(\frac{h}{H}\right)^{\frac{3}{2}} = \left[\left(1 + \frac{h}{H}\right)^{\frac{3}{2}} - \left(\frac{h}{H}\right)^{\frac{3}{2}}\right]. \qquad (4)$$

By definition

$$h = \frac{v^2}{2g} = \frac{Q^2}{S^2 2g} = \frac{3{\cdot}33^2 (L - 0{\cdot}1\, nH)^2 (H^{\frac{3}{2}})^2 K^2}{S^2\, 2g} = c \left(\frac{1}{D}\right)^2 H^3 K^2$$

(c being $\frac{3{\cdot}33^2}{2g}$ and D being $\frac{S}{(L - 0{\cdot}1\, nH)}$): dividing this last equation by H gives

$$\frac{h}{H} = c \left(\frac{H}{D}\right)^2 K^2, \tag{5}$$

which being substituted in equation (4) gives as a value for K

$$K = (1 + c \left(\frac{H}{D}\right)^2 K^2)^{\frac{1}{2}} - (c \left(\frac{H}{D}\right)^2 K^2)^{\frac{1}{2}}. \tag{6}$$

By solving equation (6), values of K corresponding to $\left(\frac{H}{D}\right)$ for every half hundredth up to 0·36 (the limit of the formula) have been computed, furnishing the requisite data for constructing a suitable curve.

It is found that this curve may be obtained very nearly by the formula

$$K = 1 + 0{\cdot}2489 \left(\frac{H}{D}\right)^2,$$

in which (within the limits before mentioned) the error will not exceed $\frac{1}{200}$ of 1 per cent.

If an error of $\frac{1}{50}$ of 1 per cent. is admissible, the formula

$$K = 1 + \left(\frac{H}{2D}\right)^2$$

will be found better adapted to rapid computations with the aid of a table of squares.

In obtaining $\left(\frac{H}{D}\right)$ it should be borne in mind that $D = \frac{S}{(L - 0{\cdot}1\, nH)}$, as above.

In case there are no end contractions, n becomes zero, and $D = \frac{S}{L}$ = depth of channel of approach.

Lowell, Mass., April 15th, 1884.

TABLE

SHOWING THE VALUE OF K COMPUTED BY THE FORMULA

$$K = (1 + c\left(\frac{H}{D}\right)^2 K^2)^{\frac{1}{2}} - (c\left(\frac{H}{D}\right)^2 K^2)^{\frac{1}{2}}$$

$\left(\frac{H}{D}\right)$	K	$\left(\frac{H}{D}\right)$	K	$\left(\frac{H}{D}\right)$	K
0·000	1·000000	0·125	1·003933	0·245	1·014931
·005	1·000006	·130	1·004251	·250	1·015543
·010	1·000026	·135	1·004581	·255	1·016167
·015	1·000058	·140	1·004923	·260	1·016805
·020	1·000103	·145	1·005278	·265	1·017455
·025	1·000161	·150	1·005644	·270	1·018117
·030	1·000231	·155	1·006023	·275	1·018792
·035	1·000314	·160	1·006414	·280	1·019480
·040	1·000409	·165	1·006817	·285	1·020180
·045	1·000518	·170	1·007232	·290	1·020893
·050	1·000638	·175	1·007659	·295	1·021620
·055	1·000772	·180	1·008099	·300	1·022359
·060	1·000917	·185	1·008551	·305	1·023110
·065	1·001075	·190	1·009015	·310	1·023875
·070	1·001246	·195	1·009491	·315	1·024653
·075	1·001429	·200	1·009980	·320	1·025444
·080	1·001624	·205	1·010480	·325	1·026248
·085	1·001832	·210	1·010994	·330	1·027065
·090	1·002051	·215	1·011519	·335	1·027895
·095	1·002284	·220	1·012057	·340	1·028739
·100	1·002528	·225	1·012607	·345	1·029596
·105	1·002785	·230	1·013169	·350	1·030467
·110	1·003053	·235	1·013744	·355	1·031350
·115	1·003335	·240	1·014331	·360	1·032248
·120	1·003628				

EXAMPLE.

DATA.

$H = 1{\cdot}954$ ft. $L = 11{\cdot}22$ ft. $n = 0$ } log. L 1·0499929
$S = L\,D = L\,(1{\cdot}954 + 5{\cdot}640) = 11{\cdot}22 \times 7{\cdot}594$ } " D 0·8804706
" S 1·9304635

PRESENT METHOD.

0·9588311 log. $3{\cdot}33\ H^{\frac{3}{2}}$
1·0499929 " $L = 11{\cdot}22$
2·0088240 " $Q_1 : Q_1 = 102{\cdot}0526$
1·9304635 " S as above.
0·0783605 " $V_1 : V_1 = \frac{Q_1}{S}$
0·1567210 " V_1^2
1·8083703 " $2g$
8·3483507 " $h_1 = \frac{V_1^2}{2g} : h_1 = {\cdot}02230$
5·0450521
7·5225260 $h_1^{\frac{3}{2}} : h_1^{\frac{3}{2}} = {\cdot}00333$
$H = 1{\cdot}95400$
$h_1 = 0{\cdot}02230$
0·2958529 log. $H + h_1 = 1{\cdot}97630$
0·8875587
0·4437793 " $(H + h_1)^{\frac{3}{2}} = 2{\cdot}77830$
0·4432583 " $(H+h_1)^{\frac{3}{2}} - h_1^{\frac{3}{2}} = 2{\cdot}77497$
1·0499929 log. L
0·5224442 " $3{\cdot}33$
2·0156954 " $Q_2 : Q_2 = 103{\cdot}6801$
1·9304335 " S
0·0852319 " $V_2 = \frac{Q_2}{S}$
0·1704638 " V_2^2
1·8083703 " $2g$
8·3620935 " $h_2 : h_2 = {\cdot}02302$
5·0862805
7·5431402 log. $h_2^{\frac{3}{2}} : h_2^{\frac{3}{2}} = {\cdot}00349$
$H = 1{\cdot}95400$
$h_2 = 0{\cdot}02302$
0·2960111 log. $H + h_2 = 1{\cdot}97702$
0·8880333
0·4440166 " $(H + h_2)^{\frac{3}{2}}$ 2·77982
0·4434711 " $(H+h_2)^{\frac{3}{2}} - h_2^{\frac{3}{2}} = 2{\cdot}77633$
1·0499929 log. L
0·5224442 " $3{\cdot}33$
2·0159082 " $Q_3 : Q_3 = 103{\cdot}7309$
1·9304635 " S
0·0854447 " V_3
0·1708894 " V_3^2
1·8083703 " $2g$
8·3625191 " $h_3 = \frac{V_3^2}{2g} : h_3 = {\cdot}02304$
5·0875573
7·5437786 " $h_3^{\frac{3}{2}} : h_3^{\frac{3}{2}} = {\cdot}00350$
$H = 1{\cdot}95400$
$h_3 = 0{\cdot}02304$
$(H+h_3) = 1{\cdot}97704$
0·2960155 log. $H + h_3 = 1{\cdot}97704$
0·8880465
0·4440232 " $(H + h_3)^{\frac{3}{2}} = 2{\cdot}77986$
0·4434758 $(H+h_3)^{\frac{3}{2}} - h_3^{\frac{3}{2}} = 2{\cdot}77636$
1·0499929 log. L
0·5224442 " $3{\cdot}33$
2·0159129 " $Q_4 : Q_4 = 103{\cdot}7320$
1·9304635 " S
0·0854494 " V_4
0·1708988 " V_4^2
1·8083703 " $2g$
8·3625285 " $h_4 : h_4 = 0{\cdot}2304$

EXAMPLE Continued.

Since h_4 is the same as h_3, it is evident that the value of Q_5 will be the same as Q_4. Therefore

$$Q = 103{\cdot}7320 \text{ } c.\ f.\ p.\ s.$$

PROPOSED METHOD.

0·2909246 log. H
0·8804706 " D

9·4104540 " $\left(\frac{H}{D}\right)$ whence $\left(\frac{H}{D}\right) = 0{\cdot}2573$

Corresponding value of K by interpolation, 1·01646.

0·0070903 log. K
0·9588311 " 3·33 $H^{\frac{3}{2}}$
1·0499929 " L

2·0159143 " Q, whence

$$Q = 103{\cdot}7324$$

BERNAUF'S TELESCOPE.—Capt. Bernauf has invented a very simple and very convenient instrument, which will often be useful for sailors. When the ocean horizon is clouded, it is difficult to measure the altitude of a star. The difficulty is obviated by a circle of iron, to which a small telescope is attached. Along the circle, in a groove, is placed a tube containing mercury. The metal occupies the lower part of the tube and oscillates according to the positions which the circle takes in the had of the observer, as it would do in the two branches of a U tube. In every position, however, the straight line, along the surfaces of the mercury in the two branches, is horizontal. The observer takes the circle in his hand, directs the telescope towards the portion of the sky which he desires to explore, and when he holds the star in the field of vision, he immediately fixes the mercury in its place by touching a button which controls an ingenious mechanism. He has then only to read, on a graduated circle, the angle formed between the direction of the telescope and that of the horizontal line.—*Les Mondes*, April 5, 1884. C.

MICROSCOPIC ORGANISMS ON THE SURFACE OF COINS.—P. F. Reinsch, having had occasion to make microscopic observations of some small silver coins, found numerous bacteria and some very characteristic algæ in the thin incrustations. Extending his observations to the copper, bronze, and gold coins, of various nations and of different values, he found that similar organisms seemed to be always present, after the coins had been in use for a year or more. They can be readily seen by scraping the surface with the point of a knife, putting the portion removed in a drop of distilled water and spreading it, with a clean knife, under a microscope which magnifies from 250 to 300 times. This discovery seems important, not only in biology, but also in the practical relations of hygiene, especially in consideration of the germ theory of disease. A portion of the erosion of the surface of coins, may perhaps be due to these organisms.—*Dingler's Journal*, March 26, 1884. C.

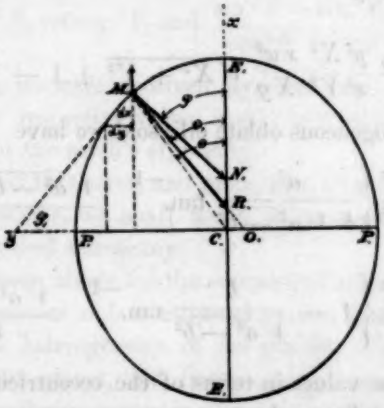
THE EARTH'S ELLIPTICITY.

By L. D'AURIA.

The present paper is intended as a continuation and an amendment of the one already published on the Ellipticity of Planets in the JOURNAL OF THE FRANKLIN INSTITUTE for May, 1884, in which, from a well-established principle of Mechanics, the following equation is deduced for the relative equilibrium of an oblate fluid ellipsoid of revolution rotating around its minor axis:

$$e^2(2-e^2) = \text{tang.}^2\,\theta.\ \text{cotang.}^2\,\theta_1\ \frac{w^2\rho}{g}\left(2-\frac{w^2\rho}{g}\right) + \frac{\sin.^2\theta - \sin.^2\theta_1}{\cos.^2\theta\,\sin.^2\theta}; \quad (1)$$

In this e, represents the eccentricity of the generating ellipse; g, the attraction at any point M of the free surface; ρ, $= MO$, the distance



on the direction of g, between the point M and the axis of rotation; w, angular velocity of rotation; θ, the angle made by the radius MC with the equatorial plane; and θ_1, the angle made by the direction of ρ, with the same plane.

The angle θ_1 is assumed smaller than the latitude φ of the same point M; this condition being absolutely necessary in order that the resultant action of attraction and centrifugal force may be normal to the free surface at M; but no definite value has been assigned to

it. If the component attractions X and Y of the point M, respectively parallel to the axes x and y, are known, then

$$\text{cotang.}^2\,\theta_1 = \frac{X^2}{Y^2};\quad \text{sin.}^2\,\theta_1 = \frac{Y^2}{X^2+Y^2};$$

and expressing tang. θ, sin. θ, cos. θ, in terms of the co-ordinates x and y; and putting

$$\rho = \frac{x}{\cos.\,\theta_1} = \frac{x}{X}\sqrt{X^2+Y^2},$$

we can write equation (1) as follows:

$$e^2(2-e^2) = \frac{y^2X^2}{x^2Y^2}\,\frac{x\,w^2}{Xg}\sqrt{X^2+Y^2}\left(2-\frac{x\,w^2}{Xg}\sqrt{X^2+Y^2}\right)+ 1-\frac{y^2X^2}{x^2Y^2}. \qquad (2)$$

Observing that in comparison with the number 2 in brackets, the quantities e^2 and $\frac{x\,w^2}{Xg}\sqrt{X^2+Y^2}$ may be neglected, we can put approximately

$$2\,e^2 = 2\,\frac{y^2X^2}{x^2Y^2}\,\frac{x\,w^2}{Xg}\sqrt{X^2+Y^2}+1-\frac{y^2X^2}{x^2Y^2}. \qquad (3)$$

Now for a homogeneous oblate ellipsoid we have

$$X = \frac{2\pi\,D\,b^2}{a^2-b^2}\left\{\frac{a^2}{b\sqrt{a^2-b^2}}\,\text{tan.}^{-1}\,\frac{\sqrt{a^2-b^2}}{b}-1\right\}x,$$

$$Y = \frac{4\pi\,D\,a^2}{a^2-b^2}\left\{1-\frac{b}{\sqrt{a^2-b^2}}\,\text{tan.}^{-1}\,\frac{\sqrt{a^2-b^2}}{b}\right\}y.$$

Expressing these values in terms of the eccentricity e, neglecting e^4 and higher powers of e, we have

$$X = \tfrac{4}{3}\pi D\,(1-\tfrac{1}{5}e^2)\,x;\quad Y = \tfrac{4}{3}\pi D\,(1+\tfrac{2}{5}e^2)\,y.$$

Substituting in equation (3) we obtain

$$2\,e^2 = 2\,\frac{(1-\frac{1}{5}e^2)^2}{(1+\frac{2}{5}e^2)^2}\,\frac{w^2}{(1-\frac{1}{5}e^2)\,g}\sqrt{x^2(1-\tfrac{1}{5}e^2)^2+y^2(1+\tfrac{2}{5}e^2)^2}+\tfrac{6}{5}e^2;$$

and putting $y = o$, x will $= a$ and $g = g_1 =$ attraction at the equator, and therefore

$$e^2 = \frac{(1-\frac{1}{5}e^2)^2}{(1+\frac{2}{5}e^2)^2}\,\frac{w^2a}{g_1} + \tfrac{3}{5}e^2;$$

or approximately

$$e^2 = \tfrac{5}{2}\,\frac{w^2a}{g_1};\ \varepsilon = \tfrac{5}{4}\,\frac{w^2a}{g_1}.$$

In the case of the earth we have

$$\frac{w^2a}{g_1} = \frac{1}{289};$$

hence

$$\varepsilon = \frac{1}{230},$$

which is exactly Newton's value given in Principia, likewise determined on the hypothesis of the earth being homogeneous.

It can be seen from the foregoing that equation (1) is perfectly sound and no element or necessary condition has been neglected in deriving it; but in assigning values to the quantities

$$\text{tang.}^2\theta,\ \text{cotang.}^2\theta_1 \text{ and } \frac{\sin.^2\theta - \sin.^2\theta_1}{\cos.^2\theta\ \ \cos.^2\theta},$$

when $\theta = \theta_1 = o$, we were deceived by their form, and thought that in this case their respective values would be 1 and o; hence the discrepancy found for the earth's ellipticity.

Having corrected this error, and made sure of the soundness of the fundamental equations, we shall touch upon a point of the utmost importance in physical astronomy.

The formulæ given above for the component attractions at a surface point of a homogeneous oblate ellipsoid cannot be applied to planets on account of the heterogeneity of the masses. But knowing from observations on our planet, that, irrespective of centrifugal force, the attraction at the surface increases in a regular manner from the equator to the poles, though not in the same proportion as if the earth were homogeneous, we can, for the degree of approximation required in this investigation, represent the component attractions at a surface point of a planet composed of strata of different densities, by

$$X = xf(e);\ \ Y = yf_1(e);$$

where x and y are the co-ordinates of the attracted point, and e, the eccentricity of the generating ellipse of the surface. However, for

more generality, it may be supposed that the functions f and f_1 contain also the eccentricities of internal strata, as well as the densities of the latter, if we please, without interfering with the result at which we aim.

Denoting by g_1 and g_2 the attractions at the equator and at the poles respectively, and substituting in equation (3) the last values of X and Y, we find for a point at the equator

$$2e^2 = 2\frac{w^2a}{g_1}\frac{f(e)^2}{f_1(e)^2} + 1 - \frac{f(e)^2}{f_1(e)^2}; \tag{4}$$

and for a point at one of the poles

$$2e^2 = 2\frac{w^2b}{g_2}\frac{f(e)}{f_1(e)} + 1 - \frac{f(e)^2}{f_1(e)^2}.$$

Hence,

$$\frac{g_1}{g_2} = \frac{a}{b}\frac{f(e)}{f_1(e)};$$

and putting $b = a(1-\varepsilon)$,

$$\frac{g_1}{g_2} = \frac{f(e)}{(1-\varepsilon)f_1(e)}.$$

On the other hand, by putting in equation (4)

$$e^2 = 2\varepsilon; \quad \frac{w^2a}{g_1} = j;$$

it becomes

$$\frac{f(e)}{f_1(e)} = \frac{(1-4\varepsilon)^{\frac{1}{2}}}{(1-2j)^{\frac{1}{2}}},$$

hence

$$\frac{g_1}{g_2} = \frac{(1-4\varepsilon)^{\frac{1}{2}}}{(1-\varepsilon)(1-2j)^{\frac{1}{2}}}.$$

Letting $\frac{g_2}{g_1} = k$, and solving for ε, we have finally

$$\varepsilon = \tfrac{1}{2}\frac{k^2 + 2j - 1}{2k^2 + 2j - 1}. \tag{5}$$

This is a very valuable equation since it gives the ellipticity of a planet composed of strata of different densities, when the ratios k and j are determined by observation.

Now we know that in the case of the earth,

approximately, $k = \frac{600}{599}$, and $j = \frac{1}{289}$;

substituting in equation (5) we find

$$\varepsilon = \frac{1}{197}$$

Since we know that at present the actual value of ε does not vary greatly from $1 \div 300$, and that the values of k and j cannot be distrusted, the discrepancy here implied must have a deep meaning, if we are correct in our mathematics. In order to investigate this meaning, let us see what change the ratio k should undergo to make ε agree with the earth's known ellipticity. It will be observed that by simply making $k = 1$ instead of $k = 600 \div 599 = 1{\cdot}00167$, we obtain

$$\varepsilon = \frac{1}{291};$$

hence a very slight diminution of k is sufficient to produce the desired effect. Let us suppose that the ratio k is not a constant quantity, but is really subject to a very slow secular change which constantly increases its value. Assuming then that the earth's mass became compact enough to retain its form at a time when the ratio k was very near or equal to unity; no discrepancy existed at that time between the theoretical and the actual value of ε; but at a later period the increase of k was not followed by a corresponding increase of ε, because the mass of the earth no longer yielded to the new conditions of the forces acting upon its particles. By aid of the assumptions above made the discrepancy above becomes easily accountable, and can be advanced as a forcible argument in favor of the present rigidity of the earth's interior.

MAGNETISM IN MADAGASCAR.—Lieut. Hallez, when stationed at Madagascar, sent a communication to the International Society of Electricians, in regard to the daily storms which are experienced upon the island. On approaching the island, the soil of which is very furruginous, the compass undergoes considerable and very abnormal deviations. This fact has induced many persons to consider Madagascar as an enormous magnet. Lieut. Hallez proposes to undertake a series of systematic observations and to communicate the results to the Society.—*Les Mondes*, March 29, 1884. C.

SUGGESTIONS FOR IMPROVEMENT IN THE MANUFACTURE OF GLASS

AND OF NEW METHODS FOR THE CONSTRUCTION OF LARGE TELESCOPIC LENSES.

By GEORGE W. HOLLEY.

[Read in Section A (Physics), at the meeting of the American Association for the Advancement of Science, held at Cincinnati, Ohio, August, 1881.]

It is many years since Sir David Brewster very confidently expressed the opinion that before the end of the present century the world would possess a refracting telescope with an object glass two feet in diameter, and a reflecting telescope the mirror of which would be twenty feet in diameter. And no individual of his time, by reason of his extensive scientific attainments and researches, and his exalted character as a man, was more entitled to speak authoritatively on this subject. Having read the glowing records of the sky with the patient zeal of the scholar and the devout ardor of the christian, he extended the boundaries of our knowledge by his discoveries, and enriched our literature by his writings. Undoubtedly it was his knowledge of the powers and capabilities of optical instruments that led to the expression of the opinion just quoted.

In reference to the refractor, Sir David's anticipations have been more than realized, while in reflectors only two improvements have been made: one in the manner of mounting and manipulating the speculum, the other in the process for silvering its face. Great improvements have also been made in the mechanical processes for handling, shaping and finishing all kinds of material substances, and of melting in large masses all fusible matter. By reason of these improvements it has become possible to construct a metallic speculum of the size mentioned by Sir David. But there are so many reasons why refracting instruments should be preferred, that it is not probable that any important efforts will be made in this direction, until exhaustive experiments have demonstrated the impossibility of vast improvement in refractors.

The present inquiry, therefore, will be directed, as regards lenses, to the consideration of methods by which telescopic object glasses may be greatly increased in size and improved in efficacy.

The first requisite to success is the ability to manufacture pure,

homogeneous glass. The next is to make this into lenses that shall properly concentrate, transmit and sift, so to speak, the solar rays, the most beautiful and exacting of all the imponderables. In 1776, M. Brisson in a report to the French Academy, on the results of experiments made with the Trudaine lens, so-called, says: "We ought to consider it impossible to make a perfect glass lens of large size." Sir David Brewster in his treatise on "New Philosophical Instruments," referring to the astronomical telescope, says: "The imperfection of this instrument arises from two causes; from the partial correction of color which is a consequence of an inequality in the colored spaces of the spectra produced by crown and flint glass, and from the difficulty of procuring flint glass free from veins or specks."

While the votaries of science in view of their triumphs during the last fifty years will be reluctant to admit the word "impossible" into their vocabulary of progress, still it must be admitted that M. Brisson's incredulity was quite justifiable since we stand to-day, more than a century after his prophetic utterance, in almost hopeless contemplation of the problem, how we are to obtain pure, homogeneous glass in the desired masses if we are to depend upon the old methods of manufacture. A slight increase in the diameter and thickness of the unground lens greatly increases the difficulty of securing homogeneity in the mass. It is said that the stewards of the magnificent bequest of Mr. James Lick, with ample funds in hand to raise, in the pure atmosphere of some one of the Rocky Mountain summits, an instrument far superior to any now in existence, are standing with folded hands unwilling to go forward because they have no assurance that even moderate success will reward their expenditure and satisfy the wish of their generous patron. The largest lens that the world renowned opticians, the Messrs. Clark and Sons, of Cambridge, were willing to undertake for Prof. Struve in behalf of the Emperor of Russia, to be placed in the famous observatory at Pulkova, is to be only 31 inches in diameter, so the world waits for its great telescope. With genius, gold and good-will to aid the grand scheme it would seem that success should be assured. Are we to be fettered and foiled by the old methods and practices whose maximum of utility seems to have been long since exhausted? Let us consider some facts that make for the negative of this question. And first the process of glass making demands attention. It can hardly be said to have been improved since the time of Dolland, Frauenhofer and Guinaud, when England, Germany

and France were honorable and earnest competitors in the good work. But the *quality* of the glass has been improved because it is made of better material—the silicious sand of Massachusetts, the purest bed of which, known to the world, was discovered some years since in Berkshire county in that State. This is now sent to the manufacturers of the finest glass in England and on the Continent, and although they cannot yet make it pure in masses large enough to satisfy the desires of the most advanced opticians, still it is true that thin plates of glass of great size and purity can be made. It is only necessary to look into the magnificent mirrors which adorn the dwellings of some of our wealthy citizens, to be convinced of this fact. It is also true that *bars* of glass of great purity, from two to four inches square, and from ten to twenty inches long can be made.

Mr. Charles Tomlinson in his "Cyclopedia of Useful Arts and Manufactures" mentions the fact that "agitation of glass, while in a liquid state, improves its quality," and it is believed that this discovery was made by the Dolland's and is the secret of their great success in glass-making. It is also believed that the best living manufacturers of glass for optical purposes, the Messrs. Glance, of Birmingham, England, are indebted to the same secret for their eminient success in the art. But the present arrangement of melting pots and ovens is such as to render thorough agitation almost impossible and also restricts, within narrow limits, the size of the masses of glass that can be produced.

A remedy for these hitherto insurmountable difficulties seems to be offered by the use of a most important modern invention, the rotating gas furnace which produces the highest available temperature—about 4,600° F.—, and will supply the largest masses of metal and at the same time secure any degree of agitation that may be desired. As a general rule it is certain that the more thoroughly liquid a metal can be made the more likely it is to be pure in quality and homogeneous in structure. The benefit resulting from the improved process for silvering the surface of glass reflectors has recently been demonstrated by the superior speculum constructed for Mr. A. Ainslee Common which is 37½ inches in diameter, is mounted at Ealing and has proved a decided success. The first speculum made for him, after it was just ready for mounting was lost by bursting "into a thousand pieces," a calamity that can only happen .to those that are made of solid glass. By the methods of construction hereinafter proposed such a misfortune would be impossible.

The silvering of the surface of glass, to improve its refractive power,

naturally suggests the introduction of the metal, in some form, in the manufacture of the glass, as has long been done with lead and other metals. Doubtless experiment would demonstrate that by using the metallic silver properly comminuted, or some of its compounds, in making the glass the refractive power of the latter and its optical value would be very greatly increased.*

Having secured glass of the desired purity the next step is to make the lens. From the ability to procure much larger masses of pure glass, by the use of the new style of furnace, than have hitherto been attainable, results in the possibility of making much larger solid lenses than have ever yet been attempted. Whether the maximum of success can be obtained in this direction experiment only can determine. But it is beleived that maximum can best be obtained by adopting an entirely new method or methods of lens construction. Before describing them a few preliminary observations will be useful. Many persons who have had occasion to use opera glasses and spectacles have noticed that a cleavage or crack in the lenses does not injure their power to produce correct images provided the edges of the crack are not crap'd or ragged. The writer used for some years a telescope, the object glass of which had a crack entirely accross it. But it was not perceptible to the eye when directed to a distant object nor did it impair the image or produce unusual diffraction of the solar rays. We may also note the fact that the firm adhesion of different parallel surfaces of glass, after they have been properly prepared, is secured by the use of transparent cements which do not impair their refractive power. It may be further noted that the sand blast, recently utilized, is used by the Messrs. Clark in shaping unground lenses, which process they also find to be greatly facilitated by the use of the chilled cast iron globules introduced by Mr. B. C. Tilghman, of Philadelphia.

Such being the facts, it is proposed to make the pure silver-bearing glass into bars, two or three inches square and ten to twenty inches long, or such size as experiment shall prove to be best; and, after properly testing every bar, to select for use only those that prove to be absolutely pure and homogeneous. But for this experiment, bars of the very pure glass, made by the Messrs. Glance, could be used, and if

* It may be that M. M. Feil and Son of Paris, who have experimented extensively and skillfully in glass-making have made experiments in this direction; but if so the writer has met no account of them.

the experiment proved a success—if a perfect lens of a given power should be constructed—then further effort to secure solid lenses of the same or greater power would be unnecessary.

President Barnard, of Columbia College, having acted as one of the United States Commissioners to report upon the Paris Exposition in 1867, and the mechanical department and instruments of precision having been assigned to him, states in his report that M. Steinheil, of Munich, exhibited "hollow prisms" . . . that "were formed of plates of plane glass" and "united without cement, being made water-tight by the perfection and polish of their surfaces," a most important fact bearing upon this inquiry, since this perfect finish, in addition to the use of cement, would insure an adhesion of the surfaces of plates or bars which it would be difficult to overcome.

Having secured a sufficient number of bars of the highest attainable purity and finish, let the cement be applied, and then lay or pile them together like cordwood, until a block of any required size is obtained. Let these be bound firmly together with steel hoops, or otherwise, and afterward shaped and finished as may be desired. It is not supposed that the slight amount of polarized light which would be produced around the circumference by the strongest pressure would effect the functions of the lens. Large and thin plates of the same kind of glass could be prepared and cemented together in a similar manner, the largest plate being placed in the middle of the pile, with those on the two sides of it diminishing somewhat in diameter, until the neces-sary thickness should be obtained, after which they could be shaped and finished. When finished their surfaces would present a series of concentric rings on each side of the middle plate. Lenses made after either of these plans would not be in danger of destruction by such an accident as occurred to Mr. Common's large speculum, before noticed, since they could not burst from unequal expansion or contraction.

It will be observed that the two methods of construction here proposed are suggested by that most beautiful piece of mechanism the human eye. In proof of this, it is only necessary to note some elementary facts concerning the structure of the eye. Its globe, or ball, is enclosed in a wall composed of three membranes—the sclerotic, choroid and retina. Its outer lens—the cornea—consists of several concentric layers of transparent, homogeneous matter. The choroid is a thin membrane which adheres loosely to the sclerotic, except at a

single point—the oculus fundus. It is void of fibres, but is traversed by numerous minute blood vessels, which intersect in all directions, forming a complete network over all its posterior surface. The retina is a thin, very delicate membrane, which lines, without adhering to, the choroid. It is translucent, serving as it were the purpose of a silver coating for the reception of the luminous rays. Behind this is the black pigment, so called, which serves as a cushion to receive the rays of light, and to absorb, within certain limits, the superfluous rays. This pigment also makes the retina a mirror,* a fact not before mentioned, so far as the writer knows, perhaps because it is so obvious that other writers have not thought it necessary to mention it.

Another interior membrane is the hyaloid, which encloses the vitreous humor. It is not a continuous, simple substance, but is partitioned off into numerous cells, which contain the fluid. Even the crystalline lens—the most solid portion of the eye—is composed of three parts, a bulb-like capsule enclosing a central lens, which is a combination of concentric plates.

Thus we learn that, in its whole structure, the eye presents almost innumerable surfaces to the luminous rays. This is a special and most prominent feature in its construction. May it not be possible that we have hitherto failed to recognize its significance, that the chief characteristic of a method of construction which an optician would condemn is the very one that the Divine Architect designed should both prevent spherical aberration, and secure, as far as possible, the achromatization of the solar rays? The methods of constructing lenses herein proposed, involve precisely the same structure in a modified form. And while it is not always safe to reason from the less to the greater, still experiment may prove it to be true that these methods of combining a number of surfaces which may be presented to the solar rays at different angles, will cause them to be so blended and mingled that both aberration and prismatic discoloration may be practically neutralized. Whether the principles involved in the method of construction adopted by the Creator were correct or otherwise, they seem to have been controlling, and we cannot go far wrong in the endeavor to copy his work.

Summarily stated the ends herein proposed to be attained are:

1. To improve the quality of glass by introducing silver into its composition, and to increase the quantity that can be produced at a

* As is proved by the Opthalmoscope.

single melting by using the rotating gas furnace which will secure any required degree of agitation of the liquid mass.

2. While the attempt to make large solid lenses may be successful, still to make the effort to secure better results by adopting the new methods of construction herein described.

That the difficulties connected with the undertaking are formidable cannot be denied, but that they are insurmountable, who will venture to assert, after recalling to mind the physical and mechanical triumphs of the last half century? If success shall crown earnest and well-directed effort, it will be worth to the world all possible cost.

SURVEYS FOR THE FUTURE WATER SUPPLY OF PHILADELPHIA.*

By Rudolph Hering. C. E., *Assistant in Charge.*

Philadelphia Water Department,

January 27, 1884.

Col. William Ludlow, *Chief Engineer.*

Sir:—I have the honor to present to you herewith the following report of the progress of the Surveys for the Future Water Supply of the City of Philadelphia, during the past year.

In accordance with your instructions, the first object was to collect the information already in existence, and also all suggestions covering the question of increasing and improving the present supply, and to make a general examination into the entire subject.

The results of this preliminary inquiry were as follows, the information being recorded as nearly as possible, in chronological order:†

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* Annual Report of the Chief of the Water Department of the City of Philadelphia, 1883.

† List of publications relationg to the subject of the Future Water Supply of the City of Philadelphia:

1. Annual Reports of the Water Department, from 1856 to 1882.

2. Reports of a special committee of the Commissioners of Fairmount Park upon the Preservation of the Purity of the Water Supply, October, 1867.

3. Proposition of certain manufacturers of Manayunk for supplying the City of Philadelphia with pure water, contained in a memorial to the State Legislature, February, 1868.

As early as 1856, efforts were made to secure a better water supply for the city. The Schuylkill valley was being rapidly built up above the city, and the quality of the water, owing to the additional refuse cast into it, was becoming correspondingly less pure.

In 1858, the Chief Engineer of the water Department, Mr. H. M. P. Birkinbine, urged that other sources than the Schuylkill be investigated, and made a preliminary report on the subject.

He considered the Wissahickon, the Delaware and the Lehigh at Easton, also the Schuylkill above Reading; rejected them all as unsuitable, and recommended an examination into the small watersheds about the city.

In 1863, I. S. Cassin, Chief Engineer of the Water Department, in his annual report, likewise urged the necessity for securing a better supply.

In 1864, Mr. Birkinbine, again Chief Engineer, was granted an

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4. On the Water Supply of Philadelphia. Pamphlet, by James Haworth, 1871.

5. Memorial to City Councils on supplying the City of Philadelphia with water from the Schuylkill and Wissahickon, by James Haworth, 1875.

6. On the Water Supply of Philadelphia. Pamphlet, by J. W. Nystrom, 1875.

7. Report on the Present and Future Water Supply for the City of Philadelphia, made to Councils by a Commission of Engineers, 1875.

8. Rainfall on the Basin of the Schuylkill River. Paper, by H. M. P. Birkinbine, JOURNAL FRANKLIN INSTITUTE, March and May, 1876.

9. Future Water Supply of the City of Philadelphia. Two papers, by H. M. P. Birkinbine, JOURNAL FRANKLIN INSTITUTE, May and July, 1878.

10. The Water Supply of Philadelphia. Paper by Charles G. Darrach, Proceedings of the Engineers' Club, Philadelphia, May, 1879.

11. The Future Water Supply of the City of Philadelphia. Paper, by James F. Smith, JOURNAL FRANKLIN INSTITUTE, October, 1879.

12. The Future Water Supply of Philadelphia. Paper, by H. M. P. Birkinbine, JOURNAL FRANKLIN INSTITUTE, November, 1879.

13. The Philadelphia Water Supply. Report of a Commission to James Haworth, 1880.

14. Report on Drainage from the Falls of Schuylkill, November, 1882, and on the Pollution of the Schuylkill River, January, 1883, by Russell Thayer, Superintendent of Fairmount Park.

15. Report on the Pollution of the Schuylkill River, etc., to the Commissioners of Fairmount Park, by Dr. Charles M. Cresson, January, 1883.

16. Potability of the Schuylkill Water Supply. Report to a Board of Experts, by Professor A. R. Leeds, January, 1883.

17. Reports on the Philadelphia Water Supply, made to Councils, by a Board of Experts, October, 1882, and April, 1883.

appropriation to make surveys for a supply of water to be brought from beyond the limits of the city, which resulted in a reconnoissance of all the creeks and streams within a radius of 40 Miles.

The following year he submitted a report. He had examined the Chester, Ridley, Crum, Darby, Cobb's, Mill, Gulf and East Valley creeks on the west side of the Schuylkill; and the Wissahickon and Plymouth creeks, the Sawmill Run, Stony and Perkiomen creeks on the east side.

The report gives the quantity of water available from each, the location of storage reservoirs, etc., and concludes with recommending a gravity supply from the Perkiomen, with a delivery into the city at an elevation of 175 feet above datum, from a storage reservoir to be located above Schwenksville, requiring a dam across the valley 65 feet high, which would impound the water from an area of 220 square miles.

The scheme is advocated with some force and supported by a large number of data, as far as they were available at the time. If sufficient storage capacity were provided, it was claimed that 240 millions of gallons daily could be furnished to the city from this source.

In 1866, the Fairmount Park Commission was created to secure such lands along the Schuylkill and Wissahickon as might be necessary to prevent the pollution of both streams, and to convert them into a public park. By this means it was expected to maintain the purity of the water supply.

On account of the objections that had been raised against the Perkiomen project by the Fairmount Park Commissioners and others, Mr. Birkinbine in his report to Councils for the year 1866, again discusses the scheme and endeavors to answer the disputed points by giving additional facts.

From a number of comparisons with similar works he confidently estimates the daily average supply from the proposed reservoirs at Zieglersville to be at least 150 million gallons. He also states that the water in this basin cannot become stagnant on account of its size and depth, but that it will rather be improved by allowing the suspended matter to settle. He finally argues that the valley offers no inducements for factories, and therefore no elements for a pollution of the water.

In 1867, a Special Committee of the Fairmount Park Commission, consisting of Fred. Graff, John C. Cresson, George G. Meade, Strick-

land Kneass and William Sellers, reported on the preservation of the purity of the city's water supply, with the conclusion that the Schuylkill river can be relied on for many years if proper means be taken early to guard it from pollution, especially by building an intercepting sewer from Manayunk to below the Fairmount dam, and if large retaining compensating reservoirs are built in the Upper Schuylkill to supply additional water during droughts.

By this latter means it was computed that the average flow of the river would give sufficient water power to raise into distributing reservoirs at Philadelphia over 116 million gallons per day through the driest period of the year.

In the following year, 1868, a bill was presented to the State Legislature, providing for the maintenance of the purity of the Schuylkill river between Norristown and Fairmount. While pending, a memorial was sent to the same body by a number of manufactures in Manayunk, protesting against the passage of this bill, and recommending a plan which, it was thought, would accomplish the same object, namely, to supply the City of Philadelphia with water from Flat Rock Dam, by means of a conduit extending from this dam to the pumps at Fairmount.

From other quarters it was suggested, instead, to build an open canal along one or both banks of the Schuylkill, by forming an embankment in it, and thus carry the refuse water to below the dam, and use the river water for the city's supply.

Owing to the opposition, the above bill did not pass; but neither of the projects was carried out in its stead.

For several years thereafter, no action was taken in the matter of improving the quality of the supply. The increased quantity of water required was supplied by increased steam-power.

This action called forth a series of pamphlets from a citizen, James Haworth, who was eager to show that the city could be furnished with the required quantity, at a much smaller cost, by water power only, and suggested the construction of numerous impounding dams to store the water from heavy rains.

In 1874, Dr. William H. McFadden, then Chief Engineer of the Water Department, discussed the question of the future water supply. Eliminating from consideration the plan of bringing water from the Delaware Water Gap by gravity, on account of its cost, he also, for the same reason, regards it as folly to bring it from New Hope, a point

that had been suggested. The Perkiomen scheme is not considered by him for want of the necessary data. Nothing, therefore, appeared to be feasible, but to continue to use the Schuylkill water. The question of raising it into reservoirs by water-power is answered negatively, on the ground that it would require an extensive and costly system of compensating reserveirs and dams, and, quoting from the report to the Reading Railroad Company, by James F. Smith, in 1874, he concludes that, taking a most favorable view, the largest available amount thus to be secured would be 100 million gallons per day. Steam power is therefore recommended as the most economical means for increasing the water supply for the immediate future. He urges a more careful study, however, into the best scheme for a more distant period.

The same report contains the results of a chemical analysis of the Schuylkill water and notes on its pollution, by Dr. Charles M. Cresson. His conclusions are, that the Schylkill water would be sufficiently good for the city if the sewage entering below Flat Rock Dam were intercepted, and the foulest sewage entering above it purified, before draining into the river.

In 1875, a memorial was presented to Councils by James Haworth on supplying the City of Philadelphia with water from the Schuylkill and Wissahickon by water-power. It was accompanied by a paper from J. W. Nystrom, Mechanical Engineer, supporting the view that a judicious employment of water-power would render steam unnecessary for supplying the city with water.

From the variety of opinions entertained on this subject, and from the difficulties presented in clearly viewing the proper plan for the future water supply, and therefore building present works in conformity thereto, but more especially from the urgent necessity of guarding against a water famine during the time of the International Exhibition, a Commission of Experts was appointed by the Mayor, in 1875, consisting of W. Milnor Roberts, William J. McAlpine, J. W, Adams, W. E. Morris, Solomon W. Roberts, and William H. McFadden, Chief Engineer of the Water Department, to whom the entire subject of the present and future supply was referred.

As to the latter question, which alone concerns us here, the report of this Commission was unsatisfactory, from want of a comprehensive view of the question and a positive expression of opinion, due, no doubt, to the magnitude of the subject, and to the insufficient funds

and time available for making the necessary inquiries. There was an absence of any valuable suggestions or of weighty arguments in any one direction which would more clearly indicate the proper future source of supply for the city. The Perkiomen scheme was rather favorably regarded by several members of the Commission, but, in the absence of more complete surveys and other investigations, they did not feel justified in recommending it.

The following propositions are discussed in the Report of the Commission of 1875:

1. *Increase of minimum flow of the Schuylkill river by storing storm water in impounding reservoirs.*—This scheme, if the reservoirs are formed by the river itself, would be much more expensive than raising the additional water by steam at Fairmount, and is, therefore, not recommended. If impounding reservoirs are built in the Perkiomen Valley, by means of a dam at Zieglersville, which would permit the storage of more than 20,000 million gallons, the minimum flow of the Schuylkill for a period of eighty days could be doubled.

2. *Pumping with the power of Flat Rock Dam.*—The Commission presents this idea with a favorable opinion, as far as cost is concerned, and recommends it as worthy of further consideration. The increase of supply from this source is estimated at 20 million gallons per day for three months, and 27 millions per day for the remaining nine months.

3. *Prevention of the pollution of the water pumped from the Fairmount Pool.*—An intercepting sewer, as recommended by the Special Committee of the Park Commission in 1867, is pronounced to be the most effectual remedy hitherto advocated. The plan of carrying the water of Flat Rock Pool to the Fairmount pumps is also mentioned, but no decided recommendation is made in either case.

4. *Gravity supply from the Delaware Water Gap.*—From the fact that the cost of a supply from this source would be, according to the estimates of the Commission, not less than $30,000,000, the adoption of this scheme is deemed inexpedient.

5. *New Hope Projects.*—The proposition to obtain water from the Delaware at this point likewise meets with disfavor on account of its expense, the cost of two alternate schemes being estimated at $23,000,000 and $22,500,000 respectively, including capitalized cost of pumping, to supply only 75 million gallons per day. One plan is to raise water at New Hope by steam power, and thence carry it to the city in

a high-level conduit. The other is to purchase the Delaware Division of the Navigation Company's Canal, change it to a supply canal, construct nine miles of new canal and seven miles of conduit, besides pumping the water by steam power at or near Lardner's Point.

6. *Scudder's Falls Project.*—The scheme to take the Delaware water at this point, situated two and one-half miles above Trenton, is likewise discarded on account of its cost, which is estimated at $21,500,000.

It requires the purchase of the Trenton Water Power, the erection of a low dam, the building of twenty-four miles of a large supply canal and seven miles of conduit, besides pumping the water by steam power at or near Lardner's Point.

7. *Gravity Supply from the Perkiomen.*—This project is treated more at length, as it was considered the only reasonably practical plan on the score of economy. Its cost for the delivery of 100 million gallons daily is estimated at $10,000,000; for the delivery of 200 million gallons daily, at $12,000,000.

The water shed is stated to be free now and likely to remain free from causes of pollution. A suitable site for building a safe dam exists and at a point where a sufficient quantity of water can be impounded. It is assumed that fifty per cent. of the rainfall would flow into the reservoir, from which it is calculated that two million people could be supplied with eighty gallons each per day.

Considering the objections to this scheme, the Commission conlude that gravity works should not be constructed unless demanded for the purpose of obtaining a purer and better water, or unless the time is near at hand when the cost of gravity would be less than by any other means. To ascertain this relation with the required degree of exactness, the Commission recommends thorough and careful surveys for an accurate map, and estimates made in detail.

8. *Artesian Wells.*—The project of supplying the city from deep wells is laid aside on the ground that there is no probability that an adequate supply for the general use of the city could be obtained in that manner; and if there were, such plans are attended with great expense and extreme uncertainty, and in every case are more or less experimental.

No action was taken by Councils on the above recommendations concerning a thorough investigation of the Perkiomen, or of any other scheme.

Dr. McFadden, Chief Engineer of the Water Department, in his annual reports to Councils for the years 1877, 1878, and 1879, calls attention to this matter, and urges a study into a plan for an adequate future supply.

Mr. Birkinbine again contributes some information on the question, in several papers read before the Franklin Institute; one in March, 1876, on the Rainfall in the Basin of the Schuylkill River, containing valuable and interesting data; another in May of the same year, on the Relation between the Rainfall in the Schuylkill Basin and the Water discharged at Fairmount.

In May and July of the year 1878, Mr. Birkinbine gives, in the FRANKLIN INSTITUTE JOURNAL, an extended discourse on the future water supply of the city. He examines into the various schemes that have been heretofore proposed, and concludes, as formerly, by recommending the Perkiomen gravity scheme as the best and most economical one.

In May, 1879, Mr. Charles G. Darrach read a paper before the Engineers' Club of Philadelphia on the same subject. He endeavored to show that a supply by pumping is more economical than by gravity, until the quantity of water needed is 150,000,000 gallons per day, or about the year 1950. In discussing the gravity schemes, he favors the Perkiomen, but instead of a dam at Schwenksville, as proposed by Mr. Birkinbine, he recommends an intercepting canal built around what would have been the edge of the lake, with dams on the cross valleys, to avoid the high dam at Schwenksville and the consequent flooding of the populated part of the valley.

In October, 1879, the future water supply of the city is discussed by Mr. James F. Smith, Chief Engineer of the Schuylkill canals. He states that "the Perkiomen creek and its tributaries form the source from which the water for Philadelphia must eventually be brought, and gravity must be the mode of its conveyance." He criticises Mr. Birkinbine's plan, however, to the effect that the surface water at the proposed site for the reservoirs would be too low, except for the supply of the East Park Reservoir and the basins below it. The location of Mr. Smith's line begins at Green Lane, where a storage reservoir is proposed, and extends from there at an elevation of 273 feet above city datum to a terminal basin situated in the city at an elevation of 249 feet.

In the following year a pamphlet was again issued by Mr. James

Haworth, a citizen of Philadelphia, containing a report on the Philadelphia Water Supply, made to him at his request in 1878, by a Commission consisting of Messrs. J. W. Nystrom, W. Barnet Le Van and William Dennison. The document was entirely of a private nature, and set forth the opinion that, with the aid of proper impounding dams, the entire supply for Philadelphia could be furnished for nearly a century to come by the water-power of the Schuylkill River below Roxborough pool.

In June, 1882, the Mayor was again authorized by Councils to appoint a Board of Experts, to report, among other matters, on what should be done for the future water supply of the city. The Commission consisted of Messrs. E. S. Chesbrough, J. Vaughan Merrick and Frederick Graff, in conjunction with the Chief Engineer, and their report is of too recent a date to need more than a reference. They found it impracticable at the time to reach definite conclusions on the question, for the want of sufficient surveys and other data.

The present investigation, finally, is to furnish the information which, as the foregoing clearly shows, had already been urged a number of times, and was absolutely essential to a solution of the important questions at issue.

It has been your desire to have the investigation made as thorough as practicable, and that due consideration should be given to all possible solutions of the problem.

Your instructions were to have the preliminary surveys extensive and exact enough to render a re-survey of the same territory at some future time unnecessary, should slight variations in the conduit lines, or in the location of storage reservoirs, be proposed.

Accordingly, the following practicable schemes are being carefully investigated:

Water can be brought to the city from distant sources, and delivered at high elevations by gravity; or it can be brought from less distant points by gravity, but requiring some pumping; or, thirdly, it can be obtained from nearer but necessarily lower sources, and be delivered into reservoirs entirely by pumping.

SCHEMES FOR SUPPLIES BY GRAVITY.

To this class belongs the following:

1. *Delaware Water Gap.*—Although this source has been frequently

mentioned, it has always been considered of questionable value, since the distance from the city, which is over eighty miles, renders the scheme an expensive one. The cost, however, had never been carefully ascertained, and, as both the excellence and abundance of this supply are great, it was worth a thorough examination.

2. To bring the *Upper Schuylkill water* by gravity to the city will not be considered at present as it is at times charged with sulphuric acid from the coal districts at the point where it would have to be diverted, and it is likely to remain so.

3. *The Lehigh River at White Haven.*—This project, although mentioned, has met with even less favor than the Water Gap scheme, owing to the required length of conduit, which would be about one hundred miles. The unusual adaptability, however, of the Lehigh water-shed above White Haven, and of its eastern slope between this point and Mauch Chunk, to furnish potable water of an excellent quality, being free from inducements either for mining, farming or manufacture, on account of its geological features and high elevation, makes the same worthy of attention; not on account of a supposition that it might be best for any near future, for its cost at present precludes this, but on account of its possible connection with other schemes more favorable at present, but not sufficiently so to recommend their adoption without looking to the more distant future.

It seems clear that the Blue Mountains, between the Lehigh and Port Jervis, must ultimately be the source whence the water supply not only of Philadelphia, but of other cities between it and the mountains, will be brought. No inducement prevails to cultivate this territory, whilst the farming and mineral lands below it must in time increase the population and the industries to an extent that will make the pollution of the lower streams almost unavoidable.

4. *The Perkiomen Creek.*—Among all the projects for a future supply, this one has heretofore received the most attention. It was first suggested by Mr. Birkinbine, was favorably considered by the Commission of Engineers in 1875, and strongly advocated by Mr. James F. Smith, Chief Engineer of the Reading Canals.

It has, however, been impossible to give it legitimately an unqualified endorsement, for the reason that the necessary data for a full comprehension of the scheme were wanting. Moreover, there is a popular belief that the available quantity of water is insufficient, and that its quality is lacking in the necessary degree of excellence. To

definitely settle these points, a thorough investigation of this entire project, considered in all its bearings, was directed.

5. *The Neshaminy and Tohickon Creeks.*—I am not aware that these creeks have ever been proposed as available for the future water supply of the city; nor would they be worth considering as forming a scheme by themselves, because their combined water is less in quantity than the water from the Perkiomen basin, although the quality cannot differ very materially from it. But as the location of a conduit bringing this water to the city, would be identical with one bringing water from the upper Delaware, this scheme presents many advantages. It will be referred to more fully under the next head.

SCHEMES FOR SUPPLIES BY GRAVITY, SUPPLEMENTED BY PUMPING.

Among the projects grouped under the second class, namely, those by which water can be partially brought by gravity from less distant points, and partially pumped, we can mention the following, which must naturally belong to the Delaware watershed, as the purity of the Schuylkill water does not increase materially with its distance from the city:

1. *Delaware River at Scudder's Falls.*—This scheme was considered by the Commission of Engineers in 1875, and has already been outlined. Its cost removes it at present from the necessity of any serious consideration.

2. *Delaware River at New Hope.*—Two projects have been proposed to bring water from this point. They were both considered by the same Commission, and have also been already described.

3. *Delaware River at Point Pleasant.*—Above Point Pleasant the Delaware river falls about fifteen feet in two miles, therefore furnishing a considerable water power. Point Pleasant, furthermore is situated at the mouth of the Tohickon Creek, and on the only practicable conduit line to the Delaware Water Gap.

A high-level conduit therefore, starting at this point, and delivering at the city reservoirs by gravity, is a practicable scheme, possessing the following advantages: It would carry the waters from the Neshaminy and Tohickon watersheds, collected by storage dams, to the city by gravity. The deficiency could be more than supplied from the Delaware river at Point Pleasant by steam or even by water power.

The canal carries the low-water flow of the Lehigh river past this point, and therefore prevents its polluting the proposed supply. This conduit would eventually form a part of one to the Delaware Water Gap, being over one-third of its entire length.

This scheme has not been mentioned in any of the documents quoted, nor has it, to my knowledge, ever before been suggested.

SUPPLIES ENTIRELY BY PUMPING.

The projects of the third class contemplate the use of the water within the limits of the city, as at present, by pumping to the necessary elevations, either by water power or steam. Artesian wells are the only source of this kind other than the Delaware and Schuylkill rivers. With regard to these the following remarks may be made. There are localities in this city where a large amount of water could be obtained, apparently unpolluted by surface infiltrations. The probable quantity of this water could be approximated only by a very careful geological and topographical examination, probably not without the aid of borings. While it is extremely doubtful whether sufficient water could be found to supply more than a small portion of the city, it might yet be found practicable to a certain degree, in case of serious objections to all other schemes.

From the above it is evident that the extent of territory requiring investigation for the future water supply is very large, much more extensive, in fact, than the territory available for the same purposes near any of the other large cities of the Union. New York had little choice, and was naturally led to the impounding of the Croton water, Boston to several small streams lying northwest of it, Baltimore to the Gunpowder creek, Brooklyn to the small streams east of it, Cincinnati to the Ohio river, St. Louis and New Orleans to the Mississippi, and the Lake cities to the Lakes,—while Philadelphia commands a territory comprising almost the entire Delaware, Schuylkill, and Lehigh watersheds, with a number of small tributaries which may be used either independently or in connection with the main rivers. In weighing their relative advantages, it was decided, that at least the following schemes should be investigated, as they seemed to be the most practicable:

First, the Perkiomen project, in all its bearings, as it has heretofore been believed to offer the greatest advantages.

Secondly, a conduit line to the Delaware Water Gap, and the practicability of temporarily impounding the water along its course.

Thirdly, as the Perkiomen basin alone might be found to furnish an insufficient supply for a distant future, the Lehigh basin was to be examined to ascertain whether its water could be brought into the Perkiomen at a later time, in order to compare this combined project with the Delaware Water Gap scheme, which requires about the same length of conduit.

And fourthly, a sanitary survey of the Schuylkill valley was needed to show the nature and amount of the polluting elements, and the cost ascertained, as nearly as possible, of maintaining the purity of its water in the future, keeping in view an increasing development of the industries and growth of the population in the valley.

It was decided, therefore, to place two surveying parties in the field, one to work up the topographical features of the Perkiomen, the other those of the Delaware project, and a third party to take charge of the hydrographic work. In addition, a careful reconnaissance was to be made of the Lehigh water-shed, also a sanitary survey of the Schuylkill valley, and a geological survey of the respective water-sheds and of the territory over which the conduit lines were to pass.

The amount of work done by the different parties during the last year, classed as topographical, hydrographic, and miscellaneous, is as follows:

A TOPOGRAPHICAL WORK.

The information to be gained under this head was: First, the most feasible conduit routes; secondly, location for storage reservoirs; and thirdly, the physical, sanitary, and commercial features of the several water-sheds.

Under physical features were to be understood the general contour and elvation of the ground, the respective areas of woodland swamps, meadows and arable land under culvation and of the towns and villages.

Under commercial features were to be considered the questions of possible future developments on account of mineral agricultural, or other natural resources, or from being readily crossed by railroad lines.

Under sanitary features were to be classed the population, death or sick rate, the location and extent of mills, factories, slaughter-houses,

cemeteries sewage, etc., and the amount of refuse matter probably reaching the water courses.

The topography was taken with considerable care, especially for the conduits, so that a close location and estimate of the cost can be made. A preliminary inspection was first undertaken, with the assistance of the country maps and aneroid barometers, in order to avoid the running of useless lines. In considering the practicable routes, tunnels were not to be regarded as being very objectionable, as they give a safer and more durable conduit, with a tendency to lower the temperature of the water in summer, and to decrease the land damages. They save distance and increase the grade of the conduit, and the increased cost over open cutting is now much diminished by the improved appliances for tunneling.

The conduit lines were run at an elvation which would permit a discharge into the Cambria and Frankford reservoirs, or at 165 to 175 feet above city datum.

The transit lines were measured with steel tapes. The topography was filled in by triangulations, by gradienter and stadia measurements, by clinometer and slope rods. The main lines were very carefully leveled, after the method of double turning points, with very satisfactory results. Three check lines were leveled, completing circuits respectively of 97·23 miles, partially over a very rough country, with an error between the levels of the two parties of only ·997 ft., or ·0,102 ft. per mile; of 73·4 miles, with an error of only 0·473 ft., or 0·0,064 ft. per mile, and of 34·5 miles, with an error of only 0·07 foot, or 0·002 foot per mile.

During rainy days the time was occupied in calculating latitudes and departures for the plotting of the conduit lines, computing and checking bearings and distances, calculating elevations, inking field notes, cleaning and repairing tools.

(*a.*) *Perkiomen Party*, Mr. Harvey Linton, C. E., in charge.

This party began operations May 29, 1883, and remained in the field until December 17, 1883, or 175 working days, when the weather made it necessary to remove to the city and begin office work.

During this time 101·94 miles were measured with steel tape, of which 53·40 miles were for conduit lines; 325·89 miles were measured by stadia and gradienter; 200 miles of slopes were taken with clino-

meter; 3·566 vernier angles were turned; 5·719 magnetic bearings were taken with the transit; 204·44 miles were leveled with the "Y" level, and 504 bench marks were established.

The areas covered by the survey were about:

11½	square miles for conduit lines,
6	square miles for storage basins, and
90	square miles for general water-shed.
107½	square miles.

CORRESPONDENCE.

ELLIPTICITY OF PLANETS.

Editor of the Journal of the Franklin Institute:

In the number of your JOURNAL for July, 1884, I have noticed a criticism, by Prof. Chase, upon my paper on the Ellipticity of Planets, published May, 1884, in the same JOURNAL.

Perhaps my knowledge of mathematics and astronomy is too limited, or too antiquated, to enable me to fully understand Prof. Chase's harmonic system as applied to the determination of the Earth's actual oblateness; but there is surely one thing clear to me, that is, the Professor makes an unnecessary display of calculations to find a number (16·98), which he could obtain by simply taking the square root of another number he has already adopted. In fact, he accepts Newcomb's estimate of the ratio of centrifugal force to attraction at the equator, viz.: $1 \div 288{\cdot}4$; consequently $\sqrt{288{\cdot}4} = 16{\cdot}98$ must represent precisely the number of times the Earth's velocity of rotation should be increased in order that the centrifugal and centripetal forces at the equator balance each other. How the Professor can imply from this, that $1 \div 288{\cdot}4$ must be the actual oblateness of the earth I am at a loss to understand.

As to the meaning of his last paragraph where speaks of connections of Neptune with the Earth, etc., I invite the Professor to explain by what reason and how the number 16·98 connects the planet Neptune with the Earth, and what the ratio $329196 \div 16{\cdot}98$ represents. In this connection he may also please to explain why he has changed the number 327994 given in Sun-Earth Balance (this JOURNAL, May, 1884), for the other, 329196.

L. D'AURIA.

Editor of the Journal of the Franklin Institute:

I send you the records of the test of a Turbine Wheel, recently made by me, at the John P. King Cotton Mill, at Augusta, Ga., which are interesting, not only from the excellent result attained, but from the great amount of power controlled by the Prony-brake, it being one of the heaviest tests ever made, if not the heaviest, the only other one of such magnitude, to my

knowledge, being that of the Boyden Turbine at the Atlantic Mills, at Lawrence, Mass., made by Mr. Boyden himself in 1851.

The wheel at Augusta, was what is known as a "Geyelin Jouval," built by Messrs. R. D. Wood & Co., of Philadelphia, 7 feet exterior diameter, with 36 buckets, each 13·875 × 1·7217 inches, giving a total area of discharge of 860 square inches, or 5·972 square feet

The friction pulley and brake were constructed by Messrs. R. D. Wood & Co., from my directions, and were as follows: Pulley, 7 feet diameter and 2 feet face, with exterior flanges 1 inch thick and 2 inches deep.

The brake was a hoop of $\frac{3}{8}$ inch boiler iron, in two pieces, lined with segments made from 4 inch oak plank, placed vertically, so as to bring the grain of the wood at right angles to the diameter of motion of the pulley, and grooved "herring-boned," on the interior surface, to admit of the passage of the lubricant, which was soap, diluted to about the consistency of cream, and allowed to flow in a stream of the size of a quill, from two feeders, placed 18 inches, and 4 feet, from the opening in the brakes, where the tightening screw drew it together, and where there was about 18 inches free space, into which a jet of water was thrown from a hydrant in the mill yard, through a fan-shaped nozzle made of lead pipe, $2\frac{1}{2}$ inches long, and $\frac{1}{4}$ inch wide. This also served to cool the pulley, as well as aid in the lubrication. The band was attached at one end to an oak timber 17 feet long and 18 inches square, which formed the first lever, and to the other end of the band was attached by a link, a screw 2 inches diameter, which passed through this timber, and was operated upon by a gear 18 inches diameter, having the nut for the screw cut in its hub. This was driven by a pinion 6 inches diameter, the shaft of which was supported in bearings on top of the timber, and had on it a hand-wheel 3 feet diameter for the operator.

A link at the end of this brake lever, connected it with a bent lever, or scale beam, having its horizontal arm 12 feet in length, and its vertical one 6 feet. The fulcrum for the lever, and the pivot from which the scale pan was hung, were of $1\frac{3}{4}$ inches steel, knife edged and hardened, and worked in iron sockets. A hydraulic regulator, or "dash-pot," 18 inches deep and 18 inches diameter, was attached to the scale beam, 10 feet from the fulcrum, or so as just to clear the weights.

The scale beam was balanced, by a weight, attached to a chain, at the extreme outer end, and passing over a grooved pulley, 12 inches diameter, and the weight required to balance it, when the "dash-pot" was filled with water, was $292\frac{1}{2}$ pounds.

The water was measured by a hook gauge, placed at a weir 19 feet long, set in the tail race, about 100 feet below the wheels, so as to get a smooth and steady flow over the weir, and its upper edge was 4 feet 6 inches above the bottom of the race at that point.

The weir crest and sides were made of Georgia pine, having straight edges, $\frac{1}{4}$ inch thick, and beveled away "down stream," at an angle of 45°.

I was aided in the weir observations by Mr. Davidson, the City Engineer of Augusta, who was kind enough to volunteer his services, and as the water was very muddy, Mr. A. L. Olmstead, C. E., of Lockport, New York, who enlarged and rebuilt the canal system at Augusta, very kindly determined the weight of a cubic foot of it for me by actual experiment, finding it to be 62·95 pounds.

The point of attachment of the brake lever to the scale-beam was 14 feet 9½ inches from the centre of the wheel shaft, giving a circumference of 92·9388 feet. This was doubled by the scale-beam, making the actual circumference of the brake circle = 185·8776 feet, which is the basis of the calculation. The intended velocity of wheel was 76·24 revolutions per minute, and 76·19 revolutions was accepted as decisive; this speed was counted by a worm shaft, tapped into the wheel shaft, with a gear and striker which rang a bell at every 100 revolutions. The head acting on which was determined by a float-can of galvanized iron, in a box in pit, with holes in bottom of box, the can supporting a light rod, graduated from line of flotation and parallel to a glass tube in which a column of water showed the height in flumes, so that the acting head was read at once.

SAMUEL WEBBER.

Test of "Geyelin Jouval" Turbine, at Augusta, Ga., May 3d, 1884, by Samuel Webber, C. E.

	No. 1.	No. 2.	No. 3.	No. 4.
Head of water acting on wheel	29·30 ft.	29·30 ft.	29·30 ft.	29·30 ft.
Weight of water per cubic foot	62·95 lbs.	62·95 lbs.	62·95 lbs.	62·95 lbs.
Weight in scale-pan	962·75 "	1,057 lbs.	1,082·5 "	1,092·5 "
Number of revolutions per minute	88·23	79·65	77·42	76·19
Whole number revolutions made	200	200	200	400
Horse-power attained by wheel	468·52	471·01	472·08	468·85
Corrected height of water on weir	Water not taken, trial only for experiment to attain proper velocity, which was fixed at 76·24 revolutions per minute.	Water not taken, trial only for experiment to attain proper velocity, which was fixed at 76·24 revolutions per minute.	1·9944 ft.	1·9853 ft.
Corrected height of waste water (⅔ deducted from this)			0·281	0·281
Cubic feet of water passing weir per minute			10190·59 ft.	10018·50 ft.
Horse-power of water, after deducting waste from of two other wheels in same pit, or ⅔ of total leakage, and correcting for velocity of approach to weir = 0·852 ft. per sec			569·57	559·95
Coefficient of useful effect of wheel			·8288	·8367
Proportionate effect of wheel in horse-power at 32 ft. head				534·78
Coefficient of discharge as compared with theoretical velocity			0·655	0·644
Ratio velocity of wheel at centre of bucket, to theoretical velocity of discharge; the velocity of wheel being intended to be that due to 24 ft. head			0·545	0.536
Ratio velocity wheel, to that of water			0·846	0·8427

Guaranteed power of wheel, 32 ft. head, 475 horse-power.
" efficiency, 80 per cent.
" discharge, 9,800 cubic feet.

Book Notices

ON AN UNSYMMETRICAL LAW OF ERROR IN THE POSITION OF A POINT IN SPACE. By E. L. De Forest, Watertown, Conn.

The readers of Professor Kendrick's late valuable journal, *The Analyst*, will remember several interesting articles by Mr. De Forest, one of which was "On an Unsymmetrical Probability Curve." In the transactions of the Connecticut Academy, Vol. vi, March, 1884, the discussion is extended so as to cover a similar law of error in the position of a point in space. It suggests several points which are well worth the consideration of mathematicians, a few of which we will enumerate:

1. There is a symmetry, even in the lack of symmetry, so that the evidence of law is as striking as ever.

2. The lack of symmetry is due to the insertion of a subsidiary datum. The result, therefore, increases the evidence that mathematics, like ordinary logic, can only take out what it has first put in.

3. The discussion may help even some mathematicians, to more correct ideas of what is meant by probable error, and what is really involved in the expression.

4. It may help to correct the erorneous impression, into which even so eminent a mathematician as the late Professor Clifford fell, that mathematical certainty can never be other than empirical and that we cannot assert, as an absolute truth, that two parallel lines will never meet.

5. It may also help to correct the opposite error, that it is impossible to arrive at different conclusions, in discussing mathematical questions from opposite points. Take, for instance, the following illustration:

Many readers of this journal have listened to some recent rather acrimonious discussions, among different mathematical members of the Institute, as to the practical merits of an apparatus devised for the same purpose as the bathometer, of Siemens. Different members of the committee, to which the apparatus was submitted for examination, agreed in believing that it would not work satisfactorily; but by mathematical discussions of special points they arrived at conclusions which they were unable to reconcile. If only one of the points which was discussed had been suggested, it is probable that all would have accepted the conclusion to which it led, but neither of them seems to have considered that a complete and correct decision could only be reached, after all the points had been duly weighed and the results which would harmonize them all had been satisfactorily ascertained. C.

A NEW SYSTEM OF LAYING OUT RAILWAY TURNOUTS INSTANTLY, BY INSPECTION FROM TABLES. By Jacob M. Clark. New York: D. Van Nostrand, 1884.

This very neat little volume gives, first, a table (I) of switch-lengths corresponding to different throws, and of frog distances and frog angles corresponding to different gauges and to different clear distances between two lines of a double track; for turnouts from a straight track. The chord-

deflection angles of the turnout curves, range from 1° to 50°. Tables II and III give corrective quantities to be added to, or subtracted from, the frog distances and frog angles of table I, in cases where the main line is curved. The remainder of the volume explains the principles of the method, and the manner of using the tables.

By the author's prefatory admission, this system of finding distances and angles in the case of turnouts from curves, appears to have been first made public by Mr. E. A. Gieseler in 1878, in a tract to which the writer was indebted for its introduction into the *Civil Engineer's Pocket Book* of last year, to which Mr. Clark kindly refers.

The fifteen illustrations are conveniently printed upon three folded inset sheets at the end of the book, so that any figure may be brought opposite to any page upon which it is referred to. It is to be regretted that the same regard for the reader's convenience did not lead to greater generosity in the size and lettering of the figures, and to greater exactness in the wording of the text. As it is, some of the propositions require, for their complete comprehension, a second reading; which, however, in view of the beautifully clear typography, can scarcely be complained of as a hardship.

The book forms a useful exposition, (probably the fullest that has yet appeared) of this method of laying out turnouts from curved main lines.

J. C. T., Jr.

TABLES FOR CALCULATING THE CUBIC CONTENTS OF EXCAVATIONS AND EMBANKMENTS, BY AN IMPROVED METHOD OF DIAGONALS AND SIDE TRIANGLES. By John R. Hudson, C E. New York: John Wiley & Sons, 1884.

The author's claim of novelty for this method, seems to be well founded. Like Henck's, it treats of each half of a hundred foot section of excavation, or of embankment, divided longitudinally by the central vertical plane of the road, as being composed of pyramids; but while Henck divides it into *three* pyramids, *all* quadrangular, and having a *common apex* at one end of the section, Mr. Hudson divides it into *four* pyramids. Two of these have *triangular* bases, a common apex, and one edge in common; while each of the other two has, for its quadrangular base, the half section at one of the stations, and, for its apex, one of the corners of the half cross section at the opposite station. The sum of the volumes of the two triangular pyramids is shown to be equal to that of an imaginary quadrangular prism, of length=one-third the length of the 100 feet section, and having its base=the area of an imaginary *half* cross section (inadvertently referred to as "a cross section") with a center height=the center height at one station, and a side height=the side height at the other station. The novelty of the method consists partly in the introduction and use of this prism, and partly in the employment of tables of contents, in cubic yards, of prisms 100 feet long, whose cross sections (uniform throughout each prism) are the "side triangles" (in the actual cross sections) above and below the ground surface of a *level* section of the same center height.

The "table of side triangles," for each given width of roadway and given side slope, faces the corresponding table of contents for level sections. These last do not differ from those in common use.

The operation consists in taking from these tables "of level sections" and "of side triangles," (by simple inspection and addition) the contents, in cubic yards, of four prisms, each 100 feet long, and each of uniform cross section throughout; the several cross sections being, respectively, that at one station, that at the other station, that of the imaginary prism to the right of the center plane, and that of the corresponding prism to the left of said plane. These four contents are then added together, and their sum divided by 3, the quotient giving the contents of the 100 feet station, in cubic yards.

The "distances out" are not required to be given; nor are any drawings of the end or middle cross sections, or calculations of their areas, required to be made. The author assures us, speaking no doubt from experience, that "with a little practice this method will be found rapid." That this should be the case will be readily understood when it is remembered, that, as already stated, the entire process consists in inspection of tables, addition, and division by 3. The simplicity of the operation tends, also, of course, to freedom from liability to error.

In its application, the method appears to be limited to "three level sections." For five level sections, and for side hill work, etc., it would have to be supplemented by some of the methods already in use.

J. C. T., Jr.

Selective Absorption of Solar Energy.—In the year 1800, Sir Wm. Herschel published, in the Philosophical Transactions, his remarkable researches upon obscure heat, which led him to conclude that heat is distinct from light. Subsequent writers taught that each solar ray possesses three qualities: heat, light and chemical action. Some modern investigators have concluded that the same æthereal undulations produce either heat, light or actinism, according to the absorbing nature of the substance which receives them. Dr. J. W. Draper observed that the maximum of heat was not necessarily found, in all cases, below the red portion of the spectrum. He concluded that in a normal spectrum it should be found in the orange, and proposed experiments upon spectra of diffraction, which he had no instruments delicate enough to carry out. Prof. Langley's invention of the bolometer has enabled him to obtain the following results: 1. In the diffraction spectrum, the maximum energy is found above the red and near the yellow ray. The situation of this point varies with the altitude of the sun, between a wave length of 0·55, on a clear day at noon, and 0·65, or more towards evening. 2. On comparing the ordinates for high and low altitudes of the sun in different parts of the spectrum, they are found to increase toward the ultra violet and decrease toward the infra red, appearing to follow a simple law of decreasing when the length of the wave increases. 3. By employing the logarithmic formula, which is legitimately applicable to homogeneous waves, we can pass from the curve for the interior to the curve for the exterior of the atmosphere; in other words, we can virtually transport our station of observation to a point beyond the

atmosphere, and determine the distribution of solar heat before it has been effected by the irregular absorbent action of the air. We then find that the maximum heat is between the wave lengths of 0·50 and 0·55, or nearer the green than the yellow. The measurements make it probable that the sun would appear distinctly blue to the naked eye, if it were not for the atmosphere. Our white light is not then the sum of all the radiations, but only of a part of the visible radiations. By measuring the area of the curves without and within the atmosphere, we can obtain a value for the solar constant by an entirely new method. The observations of Messrs. Pouillet and Violle gave, respectively, for this constant, 1·7 and 2·5 calories; Langley's preliminary observations gave 2·84, and he thinks that the true value is probably very little, if any, below three calories. 4. These observations increase the reasons for thinking that all the energy in any ray could be manifested as heat if it was received in a suitable medium.—*Ann. de Chim. et de Phys.*, Aug., 1883. C.

Use of Oxygen as a Refrigerant.—When liquefied in large quantities and suddenly evaporated by the instantaneous removal of pressure, oxygen does not solidify, like carbonic acid, but it leaves a crystalline deposit at the bottom of the apparatus, which soon disappears when the temperature begins to rise. Wroblewski is not yet able to say whether the crystals are composed of oxygen alone, or whether they come either wholly or in part from possible impurities. In refrigerating glass tubes the thin layer of this opaque deposit often interferes seriously with the readiness of observation. Another circumstance which adds to the difficulty of using liquid oxygen as a refrigerant is the necessity of keeping it in closed apparatus of great strength. It has not yet been obtained in a permanent form under the pressure of a single atmosphere. The containing apparatus being constructed partly of glass, there is continual danger of a serious explosion, so that experiments should be made with the protection of a strong mask for the face.—*Les Mondes*, Jan. 26, 1884. C.

Chestnut Timber.—There is a common tradition that the timbers of old churches were made of chestnut wood. If this were the case, chestnut trees must once have been common in countries where now they are extremely rare. A skillful chemist, M. Payen, has procured a large number of specimens of timber from the old churches and buildings in Paris, which he has subjected to careful examination, and he believes that none of them were chestnut. If letters are drawn upon oak and chestnut planks, by means of pure sulphate of iron dissolved in distilled water, the characters appear at once, in black, upon the oak and in deep violet upon the chestnut. Ammonia produces a red color, of short duration, upon the chestnut, paler and less distinct upon the oak. All the French and American varieties of oak show very distinctly, on their transverse sections, medullary rays crossing the woody fibres from the centre across the circumference. Chestnut timber possesses only concentric layers.—*La Science pour Tous; Les Mondes*, Feb. 9, 1884. C.

Monthly Periodicity of Auroras.—Terby has endeavored to show that there is a monthly period of the Northern auroras. He seeks to ex-

plain it by the appearance and return of the same solar spots towards the earth after a revolution of the sun upon its axis. Quetelot, the brothers Tromholt, and others, have suspected a monthly period, but their investigations have not proved decisive. On examining the photographs of the Kew Observatory, for four years, Terby found numerous coincidences between the passage of spots or groups of spots over the central meridian of the sun and auroral phenomena which were visible in Belgium on the same days. Montiguy, in his report on Terby's paper, is unwilling to admit all of his conclusions, but he thinks the subject of sufficient importance for further careful investigation.—*Bull. de l' Acad. de Belg.*, July 7, 1883. C.

Relations of Hydrogen.—T. Stacewicks (*Pharmaceutische Zeitschrift für Russland*, 1884, p. 33) compares the specific heats and densities of different substances, and comes to the strange conclusion that magnetism, electricity, heat and light are nothing else than rarefied hydrogen.—*Dingler's Journal*, April 2, 1884. C.

Moss Board.—The old moss, which forms beds of more than a foot in thickness, is found in prodigious masses at various places in Norway and Sweden. Although half decomposed, it constitutes an excellent material for the manufacture of paper; specimens of which have already been offered for sale, Cardboard has been manufactured from it, some leaves of which are 20 millimetres (·787 inch) in thickness. It is hard as wood and can be very easily dyed and polished. It is likely that this product can be substituted for wood with great advantage in many cases; for it possesses all of its good qualities and has none of its defects; it neither splits nor warps. It can therefore be employed in the manufacture of doors and windows, cornices and many ornaments. Under the hydraulic press it can receive a consistency and a power of resistance far superior to those of straw board.—*Moniteur Industriel; Chron. Industr.*, March 30, 1884. C.

Use of Caseine for Sizing.—All albuminoid substances may be used for paper sizing; but the albumen which is extracted from eggs or from blood is too expensive for general use. M. Muth, of Carlsruhe, substitutes for egg-albumen the caseine of milk, which has identically the same chemical composition. The caseine is but slightly soluble in pure water; but it may be wholly dissolved in water that is slightly alkaline; especially in very dilute aqua ammonia.—*Chron. Industr.*, March 30, 1844. C.

Phosphorizing Brass.—J. Whiting places bronze or brass wire in a solution of from $\frac{1}{2}$ to 5 per cent. of phosphorus in ether, bi-sulphide of carbon, or olive oil; 5 to 10 per cent. of sulphuric acid; and 85 to 95 per cent. of water, until the metal begins to take up the phosphorus. The wire is then drawn to one number finer and placed in a closed retort, with a thin layer of phosphorus, so that the phosphorus vapor may spread over the surface of the wire. The wire is then packed in charcoal, which is kindled, and after proper annealing the wire can again be drawn to a finer number. This process is repeated until the desired fineness is obtained. Wire thus phosphorized is very tough, takes a high polish, and is not easily corroded.—*Dingler's Journal*, Feb. 27, 1884. C.

Franklin Institute.

THE INTERNATIONAL ELECTRICAL EXHIBITION.

The illustration which appears as the frontispiece to this issue of the JOURNAL, gives a very fair representation of the buildings which will be occupied by the Institute for the purposes of the "International Electrical Exhibition," and for which extensive preparations have been, and are being made by the Committee on Exhibitions of the Board of Managers.

Since the appearance of the communication in the JOURNAL for September, 1883, the work has assumed such shape, that the Committee may at this time safely give the assurance that the Exhibition will be a large and representative one.

The demands for space by intending exhibitors some months ago, were already so large, that the Committee foresaw the necessity of providing for increasing the exhibition space at its disposal; and, on representing the case to the officers of the Pennsylvania Railroad Company, the old passenger depot adjoining the Exhibition building proper, was placed at the service of the Institute. This liberal action of the Company has nearly doubled the amount of space available for exhibition purposes, and has relieved the Committe of what threatened to be a serious embarassment.

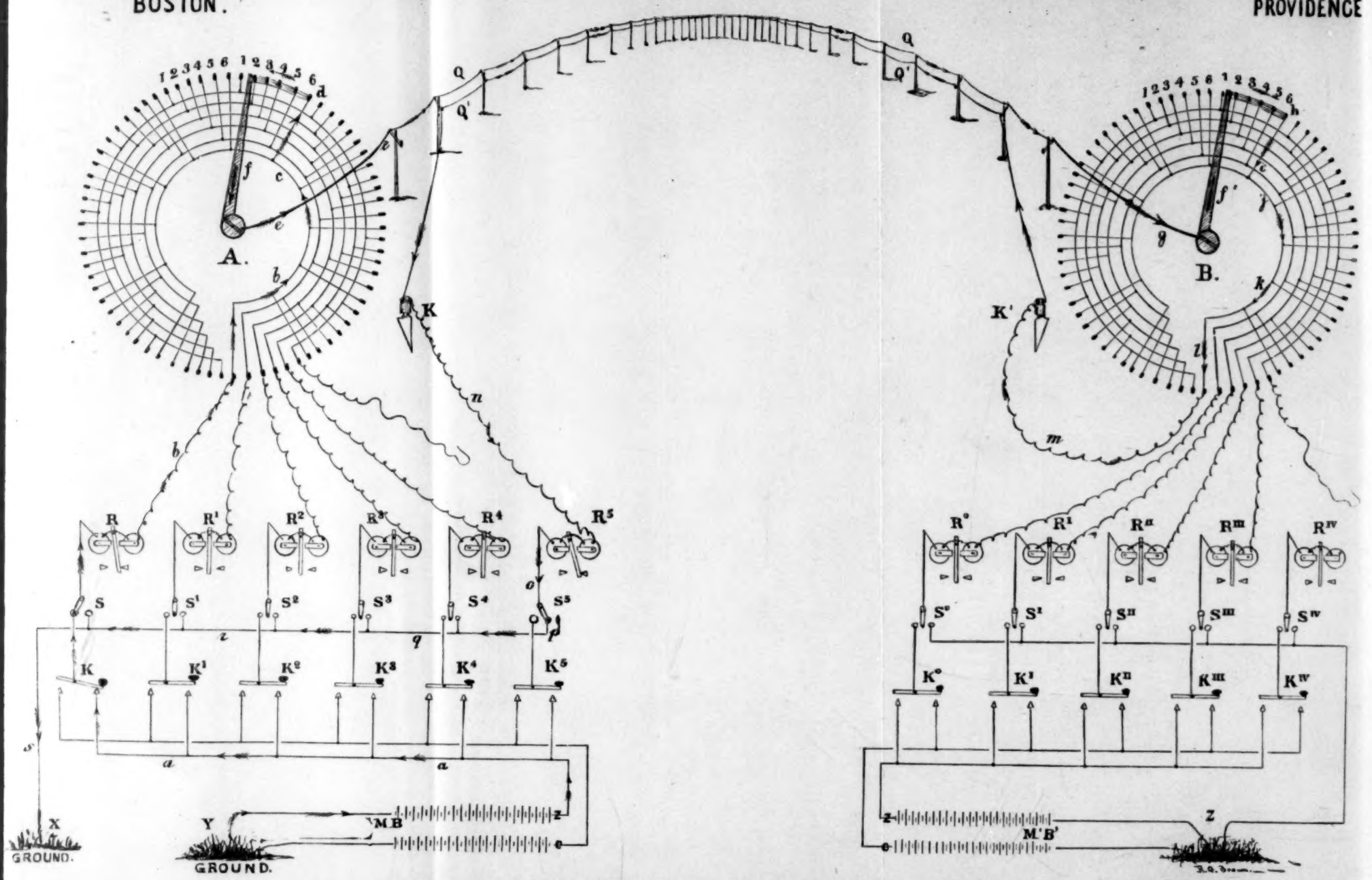
The Committee charged with the duty of preparing a schedule of the tests to be conducted of the machinery and appliances on exhibition, has elaborated a code, and has invited a large number of eminent specialists in electricity and mechanics to co-operate in the work. A Superintendent and an Electrician have been appointed by the Board, and the work of allotting space is actively going on. The main building is practically finished, and the foundations for boilers and engines are being prepared; from all of which it will be inferred that the preparations for the coming event are in a forward state.

The Committees having charge of the preparation of a bibliographical and historical collection, have met with much success in their work, and in both of these departments the exhibits promise to be large and valuable.

Early in the history of the Electrical Exhibition, a movement was started, looking to the holding of a National Congress of Electricians to convene in Philadelphia during the time of holding the Exhibition, and asking Congress to appropriate a sum of money from the National Treasury to defray the expense of the work. This project has been successfully carried out, and a commission entrusted with the task of organizing the Congress will shortly be named by the President of the United States.

It thus appears to be assured that the opportunity of utilizing the scientific forces which will be gathered together in Philadelphia at the time of the Exhibition will be improved.

W.



SYNCHRONOUS-MULTIPLEX TELEGRAPHY IN ACTUAL PRACTICE.

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SYNCHRONOUS-MULTIPLEX TELEGRAPHY IN ACTUAL PRACTICE.

By PROF. EDWIN J. HOUSTON.

It will interest the public generally to learn that Mr. Patrick B. Delany has successfully put into active operation his synchronous-multiplex system of telegraphy between the cities of Boston and Providence, R. I., a distance of about fifty miles.

The line is constructed of number six galvanized iron wire. For the purpose of securing one wire for operation in case of the accidental interruption of the other, and with a view to extension of the system, two wirés have been strung. It will of course be understood that each of these wires is intended for separate use under any of the divisions of which the synchronous-multiplex system is capable; viz., any number from a single circuit up to seventy-two separate and distinct circuits over one and the same wire; or, as these are generally used in actual practice, into six fast, or twelve slower Morse circuits; or into thirty-six, or seventy-two printing circuits.

When the possibilities of the Delany synchronous-multiplex system were first brought before the public, grave doubts were expressed by some, if not by a majority of the leading electricians of the country, as to the possibilities of its actual operation under the conditions of commercial practice. Many believed that although it might be operative under the conditions of an artificial line, established in the laboratory